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Algae of Carcoar Dam, New South Wales, Australia

V. May

(Accepted for publication 26.2.86)

Abstract

May, V. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1988. Algae of Carcoar Dam, New South Wales, Australia. Cunninghamia 2(1): 1–7. — This paper presents the results of a study of the algae of Carcoar Dam, New South Wales, Australia.

Introduction

An algal study was undertaken of Carcoar Dam (33°37′S, 149°12′E) on the Belubula River near Bathurst in the southern Central Tablelands from September 1977 to February 1981, which included a period of drought (1980–81). Inflow from the River provides high levels of nutrients from an abattoir and a sewage treatment works. Frequently the dam water appears green because of its high algal content and livestock deaths have been recorded, apparently due to toxic algae. Five stations were sampled, four in Carcoar Dam and one immediately upstream (Figure 1), at 2–4 week intervals. Methods are fully described in May & Powell (1986) from work on Chaffey Dam. A full data set, including tabular and graphic analysis, is lodged with the Library, Royal Botanic Gardens, Sydney.

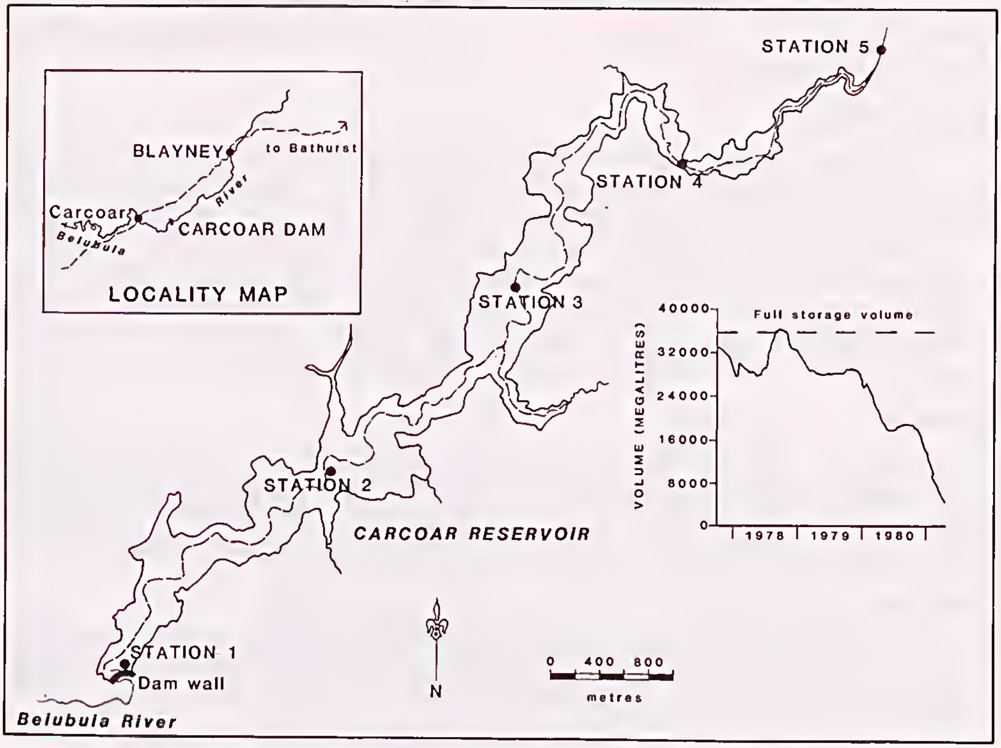

Figure 1. Location of Carcoar Dam and the Belubula River showing collecting stations and the volume stored in the dam over the study period.

Results and discussion

Sixty-one algal taxa[1] were recorded; 33 were common (frequency >5%), 24 were rare (frequency ≤5%) and four were found only as drift material (Table 1, Status). The common taxa are the chief indicators of changing conditions within the Dam; the rare species are of far less importance, but often reinforce the patterns shown by the common taxa.

Belubula River station

The Belubula River station (station 5) differed in many ways from the four dam stations, with many different species showing lower or higher frequency or abundance ratings (Table 1, Distribution Between Stations). The common taxa were present throughout the year but showed increased frequencies from late winter to summer and high abundance usually between October and November.

Seasonal growth

There were relatively fewer differences in persistence or abundance between the four dam stations than between the dam stations and the river station, with 12 of the 33 common taxa being found at all four stations within the dam in each of the first three years and at stations 1 to 3 in the fourth year (during drought) (Table 1, Persistence). Most of these occurred at any time of the year, but often were more common during summer (Table 1, Annual Distribution). Other species were less evenly distributed, appeared later in the year and usually were less common. Only *Anabaina*, *Anacystis* and *Melosira granulata* showed medium or high abundance ratings each year at all dam stations (Table 1, Abundance); *Sphaerocystis* showed a similar pattern except during the drought. Most taxa were more common in summer, but the greatest total biomass occurred later, between February and April, due largely to the very heavy growth of the blue-green algae *Anacystis* and *Anabaina*.

Depth of station

Most taxa flourished at or near the surface (top 0.5 m) rather than at lower depths. More frequent in bottom collections, however, were *Melosira granulata*, *Schizothrix*, *Staurastrum* and usually *Cyclotella* (Table 1, Vertical Distribution).

High and very high abundance ratings were recorded only in surface collections for *Anabaina* and *Anacystis* (and usually also *Sphaerocystis*), while *Melosira granulata* and *Staurastrum* became abundant or very abundant either in surface collections or equally in surface and bottom collections. Very similar results were reported for Chaffey Dam by May and Powell (1986).

Drought

From the onset of drought (February 1980), the common taxa showed differing responses: as increased or reduced frequency, slightly earlier seasonal appearance, wider distribution or greater abundance (Table 1, Drought). In addition, 12 taxa were found only during the drought period, though all were rare.

Nutrients

Stratification of the dam water occurred to a varying degree each summer (data supplied by Water Resources Commission). The associated anoxia and high nutrient levels in the bottom water, combined with adequate light penetration,

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[1] Where only one species of a genus is reported, the generic name alone is used. A full list of species names and authorities is given in Table 1.

Table 1: Species recorded from Carcoar Dam and Belubula River, together with information about their occurrence related to the position of stations, depth of water, and drought.

Taxon	1 Status	2 Dist. b. Stns.	3 Persist-ence	4 Annual Dist.	5 Abund.	6 Vert. Dist.	7 Drought
Actinastrum hantzschii Lag.	C	I	—	Jan–Mar	1	—	—
Agmenellum thermale (Kuetz.) Drouet & Daily	R	—	—	—	—	—	—
Anabaina circinalis Rabenh.	C	I	x	Jan	2	Ss	M
Anacystis cyanea *(Kuetz.) Drouet & Daily (*Microcystis aeruginosa Kuetz.*)	C	I	x	Feb	2	Ss	—
Ankistrodesmus falcatus (Corda) Ralfs	C	I	x	Sept	1	S	L
Aphanizomenon (ecophene of *Calothrix parietina* (Naeg.) Thuret)	R	—	—	—	—	—	—
Botryococcus braunii Kuetz.	C	L	x	Nov	1	S	M
Ceratium hirundinella (O. F. Muell.) Dujardin	R	—	—	—	—	—	x
Chlamydomonas sp.	R	—	—	—	—	—	x
Cladophora sp.	D	—	—	—	—	—	—
Closterium aciculare T. West	C	L	—	Feb–Mar	1	—	M
C. acutum (Lyngb.) de Bréb.	C	I	—	Apr	2	—	M
C. parvulum Naeg.	C	F	—	Jan	—	—	—
C. sp. 1	C	F	—	Jun, Dec	—	—	—
Crucigenia rectangularis (A. Braun) Gay	R	—	—	—	—	—	—
Cyclotella meneghiniana Kuetz.	C	—	x	Jan–Sept	2	B	—
Diatoms (undetermined species)	C	—	x	Dec–Jan	2	—	M
Dictyosphaerium pulchellum Wood	R	—	—	—	—	—	—
Eudorina elegans Ehrenb.	R	—	—	—	—	—	—
Euglena acus Ehrenb.	C	F	—	Jan, Aug	—	—	—
E. polymorpha Dang.	C	I	—	Feb	2	—	—
E. sp. aff. *tripteris* (Dujardin) Klebs	R	—	—	—	—	—	x
E. sp. 1	R	—	—	—	—	—	x
Glenodinium sp.	R	—	—	—	—	—	—
Gonium pectorale Muell.	R	—	—	—	—	—	—
Melosira granulata (Ehrenb.) Ralfs	C	I	x	Sept	2	B	—

Taxon	1 Status	2 Dist. b. Stns.	3 Persist- ence	4 Annual Dist.	5 Abund.	6 Vert. Dist.	7 Drought
M. varians Ag.	C	—	—	Oct–Nov	—	—	L
Micractinium pusillum Fres.	R	—	—	—	—	—	—
Microcoleus lyngbyaceus (Kuetz.) Crouan	C	—	—	Jan–Feb	—	—	M
Oedogonium sp.	D	—	—	—	—	—	—
Oocystis gigas Archer	C	L	—	Feb	1	—	—
O. parva West & West	C	I	x	Dec	1	—	—
Oscillatoria ?lutea Ag.	C	I	—	Dec	—	—	—
Pandorina morum (Muell.) Bory	C	—	—	Jun	—	—	—
Pediastrum boryanum (Turp.) Meneghini	C	F	—	Jan	—	—	—
P. duplex Meyen	C	—	—	Dec	—	—	M
Peridinium granulosum P'fair	R	—	—	—	—	—	x
Phacus caudatus Huebner	C	F	—	Jan	—	—	—
Scenedesmus abundans (Kirchner) Chodat	R	—	—	—	—	—	—
S. bijugus (Turp.) Kuetz.	C	—	—	Jan–Feb	—	—	—
S. obliquus (Turp.) Kuetz.	C	—	—	Dec–Jan	—	—	M
S. quadricaudus (Turp.) de Bréb.	C	F	—	Jan–Feb	—	—	M
Schizothrix calcicola (Ag.) Gomont	C	I	x	Dec	1	B	M
Schroederia judayi G. M. Smith	R	—	—	—	—	—	—
Selenastrum bibranum Reinsch.	R	—	—	—	—	—	x
Sphaerocystis shroeteri Chodat	C	I	x	Oct	2	S	—
Spirogyra sp.	D	—	—	—	—	—	—
Spirulina subsalsa Oersted	R	—	—	—	—	—	x
Staurastrum pingue Teiling	C	I	x	Dec–May	2	B	—
Stigeoclonium sp.	D	—	—	—	—	—	—
Synura adamsii G. M. Smith	C	—	—	Aug	1	—	—
Tetraëdron constrictum G. M. Smith	R	—	—	—	—	—	—
T. limneticum Borge	R	—	—	—	—	—	x
T. regulare Kuetz.	R	—	—	—	—	—	—
T. trigonum (Naeg.) Hansgirg	R	—	—	—	—	—	x

Tetraspora lubrica (Roth) Ag.	R	—	—	—	—	—	x
Trachelomonas armata (Ehrenb.) Stein	C	—	—	Mar–Apr	1	S	M
T. girardiana (P'fair) Deflandre	R	—	—	—	—	—	x
T. hispida (Perty) Stein	C	—	x	Jan	2	S	—
T. sp.	R	—	—	—	—	—	x
Volvox globator L.	C	L	—	Nov	1	—	—

1 Status (all species). C = Common species (>5%). R = Rare species (≤5%). D = Drift species.

2 Distribution between stations (common species). L = Lacustrine species (absent from station 5). I = Intermediate species, not strongly lacustrine or fluvial. F = Fluvial species (abundant only at station 5).

3 Persistence (common species). x = Species that occurred in all four dam stations in each of the first 3 years and in stations 1–3 during drought.

4 Annual Distribution (distribution during the year) (common species). Most common months of occurrence at most stations.

5 Abundance (common species). 1 = Medium abundance rating. 2 = High abundance rating. (Some abundance figures are also mentioned under Distribution Between Stations, Vertical Distribution, and Effect of Drought.)

6 Vertical distribution (common species). S = Frequency usually highest in surface collections. B = Frequency usually highest in bottom collections. s = abundance usually highest in surface collections.

7 Drought (effect of drought). Common species: M = species becoming more common during drought. L = species becoming less common during drought. Rare species: x = species found only during drought (1980–81).

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* *Anacystis* Meneghini (1837) is the oldest name (Drouet & Daily, 1956) available for the genus when it is treated in the broad sense including *Microcystis* Lemmermann (1907). The latter name was conserved (Lanjouw, 1961) against the earlier name *Microcystis* Kuetzing (1833), a Euglenoid genus. The type species for the genus *Anacystis* is *A. marginata* Meneghini (1837) (now = *A. montana* (Lightft.) Dr. & Daily), while the type species for the segregate genus *Microcystis* is *M. aeruginosa* (Kuetzing) Kuetzing (1848). The name of the latter species, when treated as *Anacystis*, is *A. cyanea* (Kuetzing) Drouet & Daily (1952), the name *A. aeruginosa* being already in use for a different species, *A. aeruginosa* (Zanardini) Drouet & Daily (1948).

stimulated intensive growth each year of *Anacystis* and *Anabaina*, both potentially toxic Cyanophytes. A larger biomass, indicated by higher chlorophyll *a* readings in surface water, developed when more definite stratification occurred. The very dense surface growth of blue-green algae at Station 4 parallels the results found in Burrinjuck Dam (May 1978), showing that these algae occur most often in regions just below the entry of nutrient-rich rivers into the dam. Thus, the stratification and bottom water nutrient concentration appear to control the total biomass of blue-green algae produced, but it appears to be the condition of the surface water that determines the dominant species.

Relative occurrence of *Anacystis* and *Anabaina*

It seems likely that it is changes in the conditions in the surface water, in particular changes in the concentration of available nitrogen (NO_x), that determine which of the Cyanophyte pair of species becomes dominant, the nitrogen-fixing *Anabaina* flourishing better than the non-nitrogen-fixing *Anacystis* when there is a lower NO_x concentration (see Fitzgerald, 1969). It appears that, with lower concentrations of NO_x, *Anabaina* is stimulated to fix its own atmospheric nitrogen and so can continue dense growth, provided that phosphorus is available; meantime the growth of *Anacystis* is restricted by the nitrogen shortage.

Later in the season, after April, possibly due to a drop in temperature, a reduction of biomass (and hence more available nitrogen) appears to be associated with the disappearance of *Anabaina*; some nitrogen will be recycled from the decomposition of *Anabaina* and this will further aid the growth of *Anacystis*. Ganf (1980) and Ashton (1979) have found temperature changes to be important in controlling shifts in species composition.

Comparison with other dams

The overall composition of the phytoplankton of Carcoar Dam is compared with that of other Australian Dams in Table 2. Since 1909, when the study of Yan Yean was carried out, the general incidence of blooms of Cyanophyte algae has increased (Carmichael 1981), as occurs at Carcoar and in numerous other reports. This demonstrates a drift from predominantly Chlorophycean-dominated clean water to a more enriched (polluted) water dominated by Cyanophytes with or without associated Euglenophytes.

Control measures

Traditionally, control of unwanted algae is by chemical means, by limiting the supply of nitrogen, phosphorus or both in the water (usually this comes from point sources). In Carcoar Dam at least, the practical method of controlling the excessive growth of blue-green algae is to reduce the level of phosphorus in the water, since a reduction in nitrogen is offset by extra nitrogen-fixing by *Anabaina*.

If the effects of stratification are reduced (by aerating the hypolimnion or by using artificial circulation to mix the whole water column), particularly early in the season, this could also limit the growth of blue-green algae (Pastorok *et al.* 1980).

Acknowledgements

These studies were carried out as part of the continuous study of water quality in New South Wales storages being undertaken by the Water Resources Commission of New South Wales. I am indebted to the Commission for making the water collections available to me and for other valued assistance. I also wish to thank Mr Andrew Mitchell and Dr Jocelyn Powell for their editorial comments.

Table 2: Comparison of phytoplankton composition at various Australian dams
(A = number of species; B = number of abundant genera).

	Carcoar (May, 1988)		**Chaffey** (May & Powell, 1986)		**Burrinjuck** (May, 1978)		**Yan Yean** (West, 1909)
Algal class	A	B	A	B	A	B	B
Chlorophyta	36 (59)*	4 (36)	25 (52)	8 (53)	21 (65)	88 (77)	8 (80)
Chrysophyta	5+ (8)	3 (27)	5+(10)	3 (20)	4+(13)	22 (19)	2 (20)
Cyanophyta	8 (13)	2 (18)	6 (13)	2 (13)	4 (13)	4 (3)	0 (0)
Euglenophyta	9 (15)	2†(18)	10 (21)	1 (7)	2 (6)	0 (0)	0 (0)
Pyrrhophyta	3 (5)	0 (0)	2 (4)	1 (7)	1 (3)	1 (1)	0 (0)
TOTAL	61	11	48	15	32	115	10

* Percentages in brackets
+ Understated as unidentified species grouped as 'Diatoms'
† Only at station 5

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Acacia dry scrub communities in the Byadbo area of the Snowy Mountains

K. A. Clayton-Greene and D. J. Wimbush

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Abstract

Clayton-Greene[1], K.A. and Wimbush[2], D.J. ([1]Horticultural Research Institute, P.O. Box 174, Ferntree Gully, Australia 3156; [2]CSIRO Division of Plant Industry, Canberra, Australia 2601) 1988. Acacia dry scrub communities in the Byadbo area of the Snowy Mountains. Cunninghamia 2(1): 9–24. — Acacia dry scrubs of the Byadbo area of the Kosciusko National Park and of the adjacent Cobberas-Tingaringy and Snowy River National Parks are mapped. Descriptions of eleven representative sites reveal that the scrubs are dominated by stands of *Acacia* spp. (usually *A. silvestris*) and *Eriostemon trachyphyllus*. These scrubs are virtually restricted to outcrops of sedimentary rocks and rhyodacites. Population studies indicate that these scrubs are perpetuated by occasional intense fires.

Introduction

Closed scrub communities (*sensu* Specht, 1970) are scattered throughout the mountainous Byadbo* area, mostly east of the Snowy River, near the New South Wales–Victoria border (Figure 1), at altitudes typically between 700–1100 m. These communities, hereafter referred to as dry scrubs, are dominated by *Acacia* spp. and known locally as 'black jungle' or 'black scrubs'. The local names are derived from the dark colour and impenetrability of the scrubs contrasting with the surrounding woodland (Figure 2).

The scrubs in the Byadbo area were included by Costin (1954) in the *Acacia binervia* (*glaucescens*)–*Eriostemon trachyphyllus* alliance from the lower Maclaughlin River escarpments. However, in the Monaro region *Acacia binervia* appears to be confined to a small area of scrub near the confluence of the Snowy, Maclaughlin and Delegate Rivers, and has not yet been recorded within the Kosciusko National Park. Nevertheless, many of the other species of Costin's alliance are present in the dry scrubs of the Byadbo area. The Byadbo scrubs also parallel those of the lower Maclaughlin by having an overstorey and understorey dominated respectively by monospecific stands of *Acacia* spp. and *Eriostemon trachyphyllus*.

There is little known about the botany or ecology of these dry scrubs. Forbes, Walsh & Gullen (1982) list the species occurring at eleven sites in Victoria on rocky escarpments of the Snowy River Valley. They call the vegetation 'rocky outcrop open scrubland' and it clearly includes the type of communities described by us as dry scrub. Six of the sites described by Forbes *et al.* contained both *A. silvestris* and *E. trachyphyllus*, one contained *A. falciformis* and *E. trachyphyllus* and two contained *E. trachyphyllus* but no *Acacia* spp.

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* Although local usage refers only to the area east of the Snowy River and north of the Victorian border as the Byadbo, we have for convenience extended the area to include all that shown in Figure 1 populated by dry scrubs.

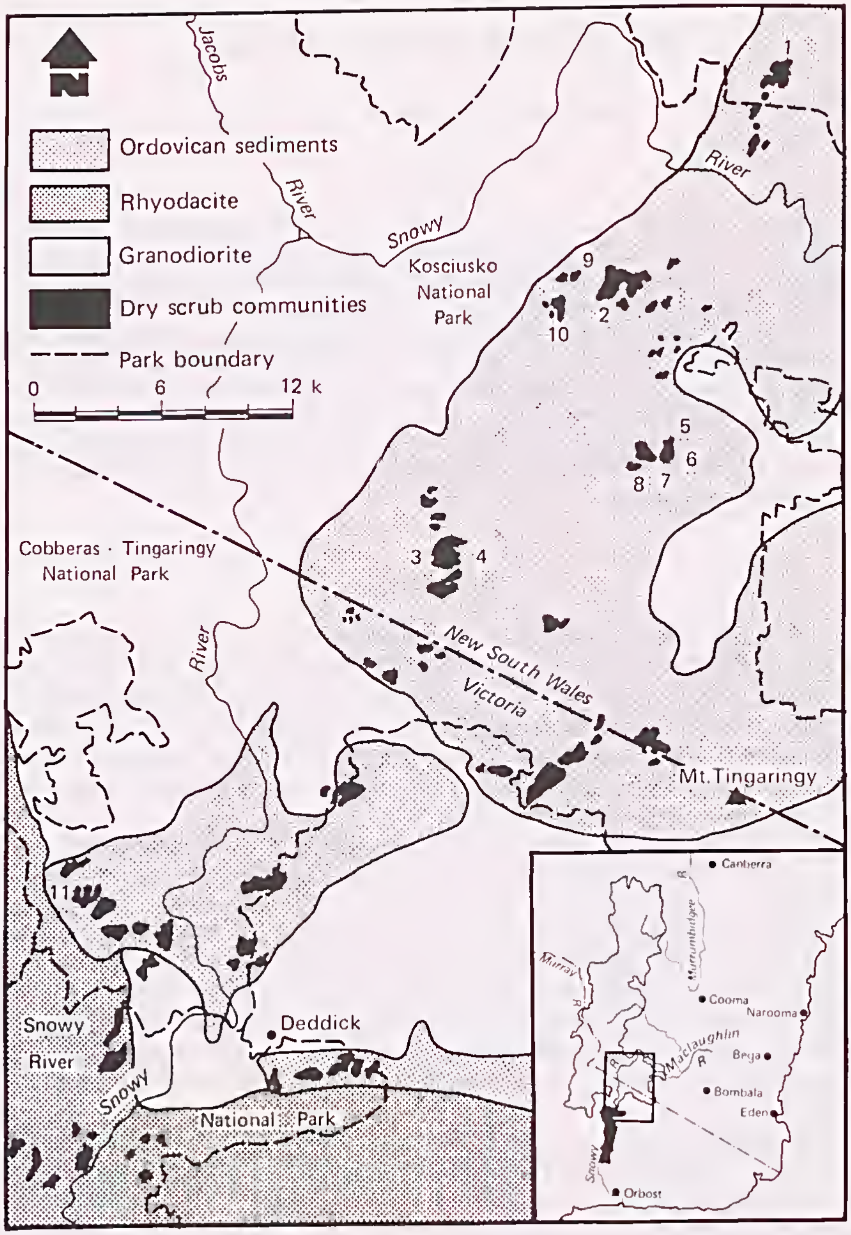

Figure 1. Distribution map of dry scrubs in the Byadbo region of the Snowy Mountains, showing their dependence on geological formation. The geology is not mapped for areas of New South Wales west of the Snowy River. Shaded areas on the inset map are, from north to south: Kosciusko National Park; existing and proposed Cobberas-Tingaringy National Park, existing and proposed Snowy River National Park.

The aim of the present study was to describe the Byadbo dry scrubs, compare them with similar scrubs elsewhere and to elucidate the processes involved in their origin and maintenance. Results would also help in formulating a management strategy for the dry scrubs of Kosciusko National Park (A. Davies, Senior Ranger, pers. comm.).

The study area

Most of the study area (Figure 1) lies within the boundary of the Kosciusko National Park (New South Wales) and the adjacent Cobberas-Tingaringy and Snowy River National Parks (Victoria). Since being explored by Robinson in 1844 (Mackaness, 1941), the area has had a history of cattle grazing, burning, and severe rabbit infestation (Costin, 1954; Clayton-Greene, 1977). Feral horses are also common, and a small feral goat population has persisted in one locality but has not increased. In recent years a system of ridgetop four-wheel drive access tracks has been established.

Climate

The entire study area is in a rain shadow protected from nearly all quarters by high mountains: the Wulgulmerang Tableland and Stradbroke Range in the south-west, the Great Dividing Range to the west and north-west, and areas of extensive upland in the south (for example Mount Tingaringy), south-east and east. Most rainfall comes from easterly airstreams which bring in moist air from the Tasman Sea.

Climatic data for the area are sparse due to the lack of settlement. Mean annual rainfall decreases in a north-easterly direction and much of the area receives around 600 mm per annum (Costin, 1954). There is a slight summer rainfall maximum, for example at Deddick (Figure 1), 67% of annual rainfall occurs between October and March.

Costin (*loc. cit.*) estimated a mean monthly temperature of 21°C in midsummer and 4°C in midwinter for areas occupied by the *A. binervia-E. trachyphyllus* alliance, and these would be comparable to the Byadbo dry scrub areas. Light snowfalls occur, but the snow does not persist. Ground frosts are common in winter, but would be less severe on the higher areas occupied by dry scrubs than on the valley floors. In summer, temperatures on the north-western aspects may reach the high thirties.

Topography, Geology and Soils

Dry scrubs occur on steep and often rocky slopes and are virtually restricted to the large areas of Upper Ordovician siltstones, schists, slates, shales and claystones which extend in a broad belt from north-east to south-west across the area (Figure 1). In the southern part, dry scrubs also occur on Lower Devonian rhyodacites. Only two small scrubs have been mapped from aerial photographs on the coarser-grained granite or granodiorite. However, because of their inaccessibility this has not been field verified. These two scrubs are adjacent to areas of rhyodacite (Figure 1) and it is possible that they are on outliers. Soils were classified by Costin (1954) as lithosols, grey-brown podzolics and colluvial brown earths.

Vegetation of the Byadbo area

The vegetation throughout the area where these dry scrubs occur is a mosaic of woodland and open-forest communities (*sensu* Specht, 1970). Below 600 m elevation, in the Snowy River valley, *Callitris columellaris* and *Eucalyptus albens* form a woodland, with the latter usually extending to altitudes well above the *C. columellaris*. Above 600–700 m, especially on southerly aspects and at lower elevations along water courses, *E. melliodora* and *E. bridgesiana* form woodlands. On the more exposed north- and west-facing slopes, above the *E. albens* communities, *E. goniocalyx* is perhaps the most widespread species with *E. nortonii*, *E. dives*, and *E. macrorhyncha* also common. The latter is particularly common on the patches of shale which occur throughout the region. Open-forest of *E. viminalis*, *E. rubida* and *E. mannifera* subsp. *maculosa* occurs on more sheltered east- and south-facing slopes. On the higher peaks, *E. pauciflora* subsp. *pauciflora*, *E. dalrympleana* and *E. radiata* form open-forest and tall open-forest.

Within these communities the dry scrubs form discrete patches, usually on north- and west-facing aspects, with abrupt boundaries between them and adjacent communities. The upper boundary often coincides with the crest of a ridge. When viewed from above, the outline of dry scrubs is very reminiscent of the pattern of burn produced by wildfires (Figures 1, 2).

Site descriptions

The canopy species that was dominant in both size and number in nine of the eleven dry scrubs was *Acacia silvestris*. In some scrubs there were scattered emergent *Exocarpos cupressiformis*. Depauperate *Eucalyptus nortonii*, *E. albens*, *E. melliodora* and *E. macrorhyncha* occurred singly or in combination both within and emergent above the canopy. *Eriostemon trachyphyllus* was common (usually the main species) in the understorey of every scrub site visited. *Olearia phlogopappa* was also common in the understorey.

Where the canopy of *A. silvestris* was more open, as in older scrubs or near the scrub–woodland boundary there were often shrubs of *Phebalium lamprophyllum*, *Platysace lanceolata*, *Helichrysum conditum*, *H. obcordatum*, *Polyscias* sp. and *Olearia iodochroa*. *Cassytha glabella* often formed a dense tangle over the smaller trees and shrubs. Herbaceous ground cover was minimal in all the scrubs visited.

Only two of the eleven scrubs examined (sites 9 and 10, Figure 2) did not contain *A. silvestris* (Table 1). At site 9 the only *Acacia* species present was *A. kettlewelliae* which is widespread in the region, particularly around other scrubs and on outcrops of shale. Together with *Eriostemon trachyphyllus* and *Daviesia mimosoides*, this species formed a discontinuous shrub layer about 3 m tall. Beneath this was an almost continuous stratum of shrubs of various species, including *Platysace lanceolata*, *Dodonaea viscosa*, *Phebalium lamprophyllum* and *Prostanthera phylicifolia*. The latter species has not been recorded elsewhere in the Byadbo area except in heaths on Mt Tingaringy (Figure 1). Small trees of *Exocarpos cupressiformis* and *Eucalyptus melliodora*, the latter showing extensive defoliation and vertical splits in the bark, were scattered emergents. At site 9 both root suckering and seedling growth of *Eriostemon trachyphyllus* were observed and there were many seedlings of *A. kettlewelliae*.

At site 10 the dominant species was *A. falciformis* growing as a small tree up to 8 m in height and forming an open canopy above a dense understorey of large old shrubs of *E. trachyphyllus* and scattered *O. phlogopappa*. *Callistemon pallidus* was growing on rock outcrops within this scrub. On adjacent slopes *A. falciformis* formed a continuous canopy with very little understorey and the rockiest sites were occupied by *Allocasuarina verticillata*.

At site 2 on areas of outcropping rock there were patches of tall *Acacia doratoxylon* within the typical *A. silvestris* canopy.

Table 1: General site data

Site Location No.	1:100 000 grid ref.	Slope (Deg.)	Aspect	Dominant *Acacia* species
1 Paupong	8626 509351	20	NW	*A. silvestris*
2 Black Jack	8626 427281	26	NW	*A. silvestris–* *A. doratoxylon*
3 Monument (a)	8626 351156	26	NE	*A. silvestris*
4 Monument (b)	8626 358158	16	W	*A. silvestris*
5 Merambago (a)	8626 462207	19	NW	*A. silvestris*
6 Merambago (b)	8626 457204	20	ENE	*A. silvestris*
7 Merambago (c)	8626 451204	20	NNE	*A. silvestris*
8 Merambago (d)	8626 449205	28	N	*A. silvestris*
9 Slaughter-house (a)	8626 417292	21	NW	*A. kettlewelliae*
10 Slaughter-house (b)	8626 408277	27	NW	*A. falciformis*
11 Wulgulmerang	8523 182995	15	NW	*A. silvestris*

The general appearance of most of the *Acacia* stands in these dry scrubs was one of uniformity, with closed canopies and stems of similar height and size. Closer examination showed that though most stems were of a similar height, there was a range of stem diameters, with occasional individuals much larger than the rest. These larger individuals were often near the periphery of the scrub. Sometimes there were several stands within a scrub, each of relatively uniform structure but clearly distinguishable from each other (Figure 3). All of the scrubs except that at site 9 showed signs of having been burnt (for example butt scars, charcoal, and standing dead trunks, especially of eucalypts).

Methods

The distribution of dry scrubs throughout the Byadbo area was mapped by plotting from aerial photographs onto 1:100 000 maps (Figure 1). During the field work a further two small scrubs were located which were not apparent on aerial photographs. Seventy-three scrubs are thus mapped in Figure 1; however, because access was difficult only eleven were visited (Figure 1 and Table 1), although several more were observed from ground vantage points and helicopter using high-powered binoculars. This enabled a confident identification of the major canopy species (*A. silvestris*).

Stand structure and dynamics were investigated at sites 2–8 (Figure 1, Table 1), using belt transects 2 m wide and 10 m, 25 m or 100 m long, depending on stand density, shorter transects being used in high densities. Within each transect stem density and diameter at height 0.2 m for both living and dead stems of *A. silvestris* and *E. trachyphyllus* were recorded. At sites 2–5, 7, 8 and 11, cross-sections of stems from the main scrub species were taken for ring counting. Those from site 8 were also checked in the Tasmanian Regional Laboratory of CSIRO Division of Forest Research.

At site 1 a line of 5 circular permanent plots each of 0.01 ha was established in May 1975. The centres of the plots were marked by steel posts spaced 25 m apart. All individual trees and shrubs (both live and dead) were counted in three height classes. Measurements were repeated in September 1982.

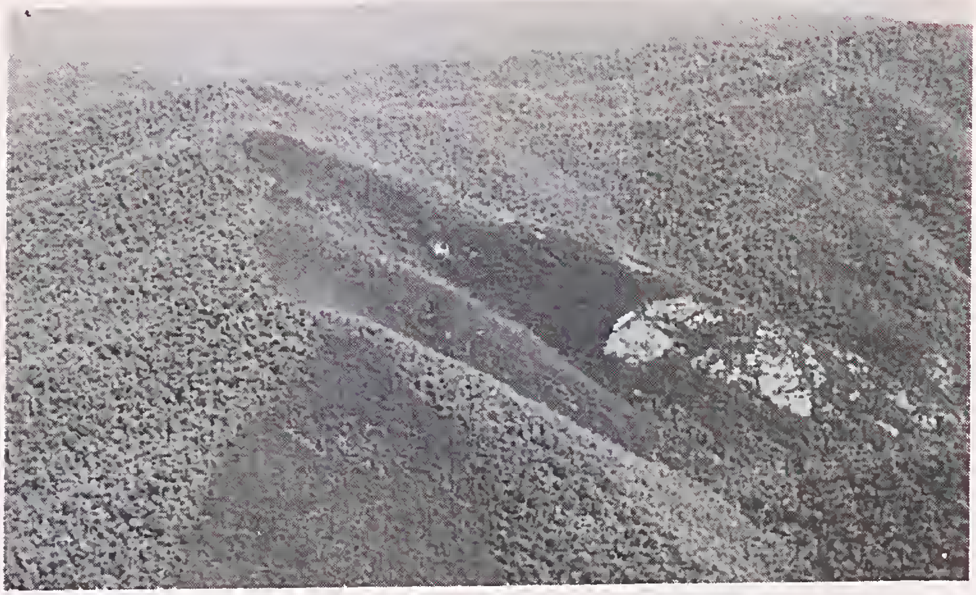

Figure 2. Oblique aerial photograph of *Acacia silvestris–Eriostemon trachyphyllus* dry scrubs at Byadbo, showing their fine texture and dark colour contrasting with the surrounding woodland.

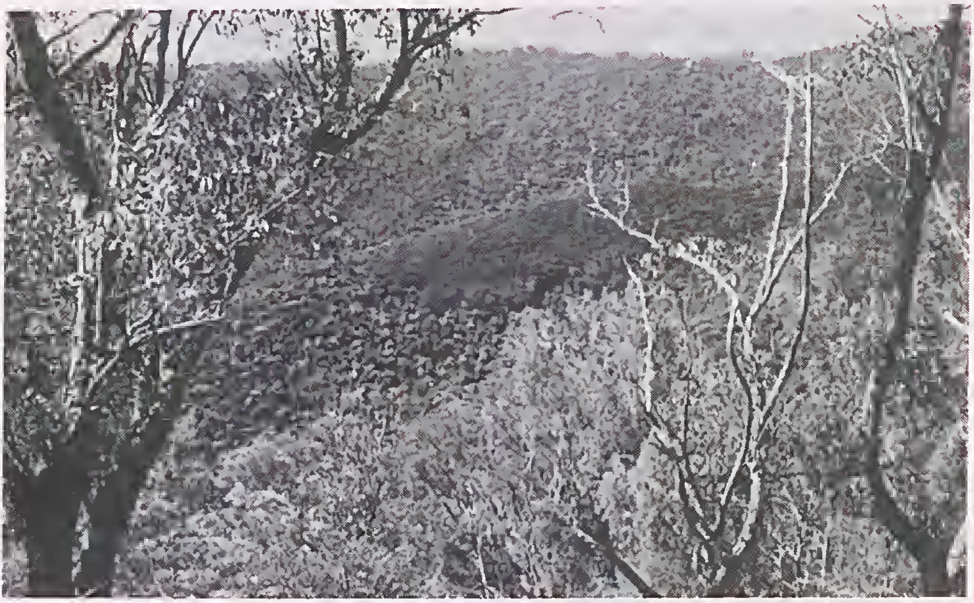

Figure 3. A view looking east over site 3 (obscured) and onto site 4 (cf. Figure 2) which was located near the upper edge of the denser patch of scrub near the centre of the photograph. Immediately below and to the left of this patch is the much older stand which includes site 3, in which the canopies are, unlike the younger ones, rounded in shape and in blossom. The vegetation in the foreground and background is mainly woodland of *Eucalyptus goniocalyx*.

Results

Stem density, basal area and size class distribution

Total live stem densities ranged from 7200 up to 68 000 per hectare (Table 2). Although stems of *E. trachyphyllus* were usually more numerous because of its multistemmed habit, *A. silvestris,* with one exception, had a higher total basal area (Table 2). Total basal area, of which *A. silvestris* comprised up to 88%, ranged from about 9 up to 42 m^2 per hectare. Basal areas were generally similar to those in the surrounding woodland (Clayton-Greene, 1981).

The diameter size-class distributions (Figure 4) showed a similarity in form both between sites and species. As in even-aged stands of *Eucalyptus regnans* F. Muell. (Ashton, 1976), they tended to conform to a normal curve, with the accumulation of suppressed individuals causing a positive skew or bimodal distribution in the younger stands. The modal size class differed widely both between sites and species. At any one site, most stems of *E. trachyphyllus* were smaller than those of *A. silvestris.*

Except at site 2, 20–30% of the total number of *Acacia* stems were dead, (Table 2) whilst the figure for *Eriostemon* was much lower (10%). At each site the size class distribution of dead stems was similar to that for living stems but these stems were on average smaller. This indicates that the stands were thinning out only gradually. Site 2 appears to be a particularly harsh environment characterized by the total basal area (8.82 m^2/ha), the high percentage of dead *Acacia* stems (50%) and the presence nearby of *A. doratoxylon.* In the Byadbo area *A. doratoxylon* typically grows in skeletal soils on rocky outcrops. Surrounding site 2 the vegetation was very open with large senescing *A. doratoxylon* (up to 8 m tall) many of which had old fire scars at their base. Underneath these trees were many small *Acacia* seedlings (less than 10 cm high) which had recently germinated in the absence of fire.

Table 2: Stem density (no. ha^{-1}) and basal area (m^2 ha^{-1}) of living stems of *Acacia silvestris* and *Eriostemon trachyphyllus* and number of dead *Acacia* stems as a percentage of the total, in seven dry scrub sites.

Site	*A. silvestris*	Density (stems ha^{-1}) *E. trachyphyllus*	Total	Dead *Acacia* stems (% of total no. of *Acacia*)
8	31,000	37,000	68,000	23
7	30,500	14,000	44,500	n.a.
6	12,000	10,500	22,500	22
4	7,750	23,750	31,500	28
2	4,916	7,830	12,746	50
5	4,100	5,500	9,600	22
3	950	6,250	7,200	21

Site	*A. silvestris*	Basal Area (m^2 ha^{-1}) *E. trachyphyllus*	Total	% *Acacia*
8	13.76	3.11	16.87	82
7	11.86	1.93	13.79	86
6	14.99	2.06	17.05	76
4	16.08	10.19	26.27	61
2	5.69	3.13	8.82	65
5	16.32	5.17	21.24	88
3	17.76	24.42	42.18	42

Ring counts

Ring counts obtained by the CSIRO Division of Forest Research in Tasmania and those obtained by the authors on the same stems were similar. At low magnification, there appeared to be distinct rings in the cross-sections from both *Acacia silvestris* and *Eriostemon trachyphyllus.* However, these rings were less well-defined at higher magnification, and in *Eriostemon* there was a strong tendency for narrow and wide rings to alternate, indicating perhaps a pause in cambial activity associated with flowering (T. Bird, pers. comm.). In the oldest trees, heart rot often made ring counting difficult.

At some localities, there were a few large stems of *Acacia silvestris* (Figure 4, Table 3) which had fire scars and were probably survivors of an older generation. Given the difficulties of accurate ring counting, and the probable failure of suppressed stems to produce rings in some years, most stems in three of the scrubs that were sampled intensively (sites 2, 7 and 11) appeared to be between 25 and 35 years old.

Aerial photographs taken in 1964 show that the scrub at site 8 had been recently defoliated by what must have been an intense fire that left clearly defined patches of scrub with unburnt canopies on or near the crests of ridges. Ring counts at site 8 confirmed the date of this fire. Furthermore, two of the *Eriostemon* stem sections from within the adjacent undefoliated ridgetop scrub at site 7, (with ring counts of 31 and 34), had 20 year-old scars. This indicates that the fire in 1964 penetrated the understorey but did not kill the vegetation at site 7.

The oldest *A. silvestris* stem sampled was 200 mm diameter and had approximately 120 rings, and the oldest *E. trachyphyllus* was 60 mm diameter with 72 rings (Table 3). In both instances they were much larger and older than surrounding trees and had survived or escaped fires. There was a fire scar at the base of the *A. silvestris.* Stems of *E. trachyphyllus* up to 200 mm diameter were observed, but not sampled.

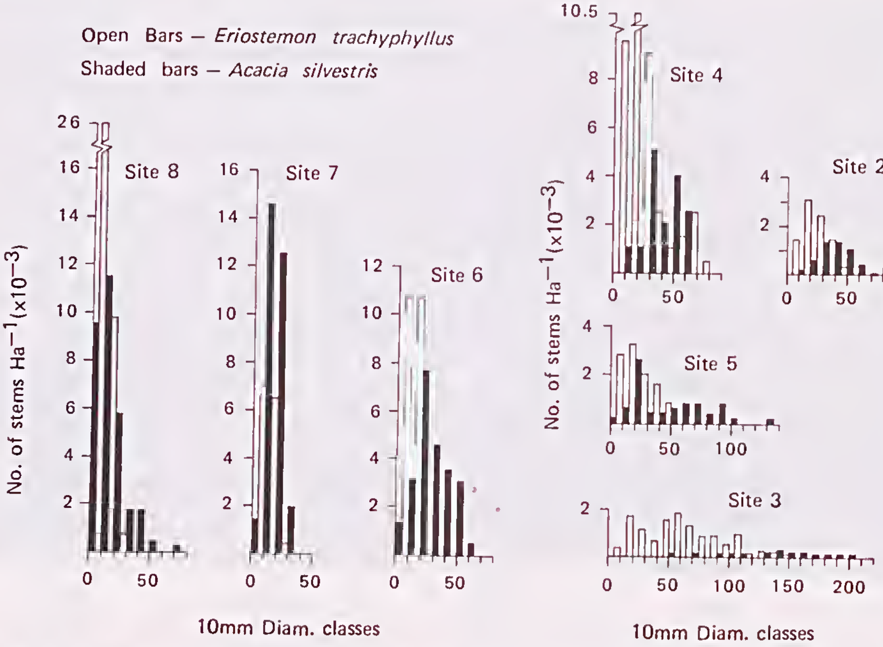

Figure 4. Size class distribution in 10 mm diameter classes of *Acacia silvestris* and *Eriostemon trachyphyllus* at sites 2–8.

Table 3: Ring counts and overbark diameters of fresh stems of *Acacia silvestris* and *Eriostemon trachyphyllus* from seven dry scrub sites.

	A. silvestris		***E. trachyphyllus***	
Site No.	Diameter (mm)	Ring count	Diameter (mm)	Ring count
2	200	120	40	42
	94	40	29	42
	89	37	29	41
	87	41	23	34
	55	30	15	30
	54	27	10	27
	45	35	9	26
	42	35	14	27
	39	30		
	38	26		
	37	27		
	34	29		
	32	29		
	32	29		
	29	21		
	27	30		
3	49	41		
4	50	42		
	46	26		
5	105	46	60	72
	44	30	20	39
7	68	34	46	32
	64	31	38	24
	39	27	37	36
	38	27	30	31
	30	26	20	34
	27	26	9	22
	26	29		
	20	22		
	19	31		
	10	12		
8	53	19	20	23
	28	19	19	17
	27	19	16	25
	21	21	8	17
	16	17	8	16
	13	17	5	10
	13	16		
	8	15		
11	56	27	16	20
	49	26	14	20
	35	26		
	21	19		

Permanent plots

The results from the permanent plots (Table 4) show a decrease in all height classes of *A. silvestris* and a reduction since 1975 in the percentage of seedlings occupying the smallest height class. *Eriostemon trachyphyllus* shows a similar reduction in the smallest height class, but numbers in the >1.0 m class remained similar over time. Of the *Olearia* spp. only *O. iodochroa* showed an increase in numbers in the smallest height class, but this species was present on only one of the five plots. The number of plots was insufficient to produce statistically significant trends.

Table 4: Mean no. of live stems/ha of four woody species in three height classes at site 1 (Paupong) in 1975 and 1982. Data summarised from 5 permanent 0.01 ha circular plots. Standard errors of the mean are shown in brackets.

	Year	Height Class (m) <0.3	0.3–1.0	>1.0	Mean no. stems per ha
Acacia silvestris	1975	180	60	3580	3820 (433)
	1982	20	40	2520	2580 (266)
Eriostemon trachyphyllus	1975	540	80	620	1240 (230)
	1985	360	100	640	1100 (286)
Olearia phlogopappa	1975	120	80	0	200 (68)
	1982	100	40	0	140 (30)
Olearia iodochroa	1975	440	100	60	600 (232)
	1982	620	60	100	780 (338)

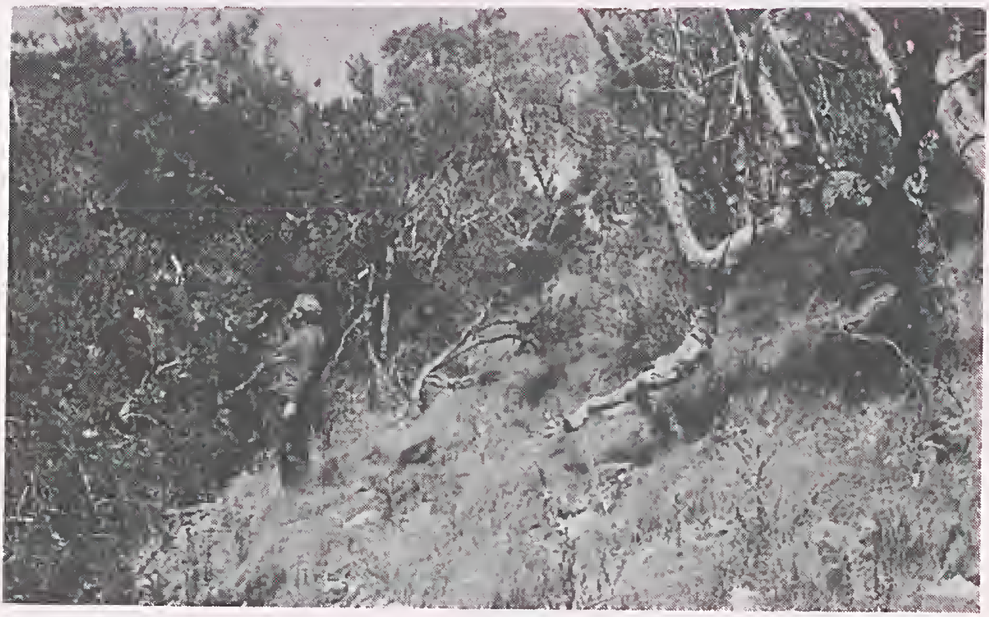

Figure 5. The upper south-western edge of the 'Monument' scrub (site 3) showing the abrupt boundary with *Eucalyptus goniocalyx* woodland on the right.

Discussion

It is clear from Figure 1 and field survey that within the Byadbo region the occurrence of these scrubs is related to lithology and aspect. Scrubs are predominantly found on north or north-west aspects and only two appear to occur on the coarse-grained soils derived from granodiorite. Another striking feature is the abrupt boundary between scrub and surrounding woodland (Figures 2, 5), there being virtually no ecotone.

Soil type, angle of slope and aspect do not appear to be critical in determining the lateral or lower boundaries of these scrubs. The boundaries often extended diagonally across slopes uniform in these attributes. However, upper boundaries normally coincided with a ridge crest. Only on a few wetter slopes with an easterly aspect (for example near site 3) were there mixtures of scrub and woodland species. A few small seedlings of *A. silvestris* were seen growing among *Chionochloa pallida* tussocks in woodland bordering the scrub. Similarly on the rocky summits of the Ballantyne Hills in the higher rainfall area near the Stradbroke Range, *Eriostemon trachyphyllus, Phebalium lamprophyllum, Dodonaea viscosa* and other typical scrub species form an understorey beneath an open canopy of *Eucalyptus dives* and *E. rubida*. In this community *A. silvestris* is absent.

Within each scrub the population is either approximately even-aged (for example site 8) or discontinuous with large gaps between ages (for example site 2). An occasional instance of suckering was observed, however most regeneration had clearly been from seed. At all sites there were few if any seedlings. The permanent plots also show no evidence of further recruitment by the main canopy species after initial establishment (Table 4). It is thus evident that each population originated from an event that killed most of the standing vegetation and resulted in seed of both *Acacia* and *Eriostemon* germinating in large numbers.

Though it is possible that the rare extreme drought or intensely cold interval could kill large areas of scrub, these would be unlikely to produce the clear boundaries that are evident between discrete stands of different ages within the one scrub (for example Figure 3). Nearly all sites had abundant evidence of fire and it seems that fire is the likely instrument of regeneration. Evidence for intense fire as the main agent of regeneration also comes from the distribution of the scrubs, the large number of dead and often fire-scarred trees, dead spars, butt-scars on older live trees and the fire history, gleaned from both local knowledge and aerial photographs.

According to local knowledge (J. Rogers pers. comm.), wildfires were widespread in the region in February 1952 and burnt site 11. Ring counts of *A. silvestris* are in accordance with this date although those of *E. trachyphyllus* may indicate a more recent fire. Similarly at site 8 the occurrence of a fire around 1964 is shown on aerial photographs and the ring counts show close agreement. Examination of the ring counts from the other sites indicates that the scrubs at sites 2 and 7 and possibly 4 and 6 also arose after the 1952 fires. Sites 3 and 5 appear to date from an earlier fire. Although the sample size is very small, two episodes of destruction are indicated at site 4 (Table 3 and Figure 3) at 30 and possibly 50 years B.P.

It is reported (J. Rogers, pers. comm.) that under extreme conditions of high temperature and strong wind, fire moves rapidly through the scrubs, but at other times they can be very difficult to burn (Forestry Commission of New South Wales, 1983). Several instances were noted where recent low intensity fires in the surrounding woodland had burnt to the edge of a scrub but failed to penetrate. On one occasion, aerial incendiaries were dropped into scrubs during control burning operations without any resulting ignition. The scrubs will evidently only ignite under hot dry windy conditions, and the fire intensity would then probably be increased by the high oil content of the living *Eriostemon* leaves and other Rutaceous plants.

Reasons for the failure of low-intensity fires to penetrate the scrub can only be speculative. These could include a dense closed canopy, lack of ground vegetation and only a moderate flammability of dead *Acacia* leaves. King & Vines (1969) reported that dried leaves of two other species of *Acacia* (*A. longifolia* var. *sophorae* and *A. maidenii*) were in the mid-range of flammability of species tested due to a relatively high total mineral content. In the dry Byadbo environment, *Acacia* litter is likely to be only slowly mineralized, thus retaining its low flammability.

Only site 9 showed no evidence of fire. This site differed from the other scrubs in being dominated by *A. kettlewelliae*, and there was a continual though sparse regeneration of the *Acacia* and other species. Site 9 was a particularly harsh site with the vegetation showing signs of frequent moisture stress. This vegetation may be an arrested succession due to frequent plant death from drought.

Site quality has a marked effect on the form of these scrubs and this is illustrated by comparing site 2 with site 7 where differences in tree size do not indicate different ages. Both have vegetation of similar age (Table 3), although their size class distributions are quite different (Figure 4). At site 7, where soil, slope and aspect are more favourable, the closed canopy is approximately 6 m in height. Stems are densely packed with the majority being 10–30 mm in diameter. Site 2 is more rocky, with skeletal soils, a steeper slope and more exposed aspect: *Acacia silvestris* is only 4 m tall, with a density <30% and a basal area <65% of those at site 7. However most stems are 30–60 mm in diameter (Figure 4), giving an impression of greater age. At site 2, due to large areas of exposed rock, seedling establishment is restricted to fewer sites. There may also be more soil moisture available at site 2 due to less transpiration. Krause & Kummerow (1977) found that chaparral vegetation in California developed greater moisture stress on a shaded slope than on an adjacent exposed slope. This was attributed to the greater amount of transpiring leaf surface area on the shaded slope. Thus although the overall environment of site 2 is harsher than site 7 individual trees may experience more favourable conditions for growth.

The fate of these scrubs if left unburnt is uncertain and the reasons for their original development can only be speculative. The data from the permanent plots (Table 4) and population structures (Figure 4) suggest that over time *E. trachyphyllus* and particularly *A. silvestris* would decline or disappear (the vegetation on the summits of the Ballantyne Hills may represent such a later seral stage).

A further striking feature of the Byadbo area is that both *A. silvestris* and *E. trachyphyllus* rarely occur in the surrounding woodland. This contrasts with *A. kettlewelliae* and *A. falciformis* which also form scrubs on sites similar to those occupied by *A. silvestris* but are common elsewhere in the area. *A. doratoxylon*, the other scrub-forming species, typically occurs on rock outcrops when not in scrubs.

Near the southern coast of New South Wales, 120 km ENE of the Byadbo area, there is another dry scrub dominated by *A. silvestris* and *E. trachyphyllus*. It is located on a west-facing slope above the Brogo River 3 km west of Mumbulla Mountain, at only 100 m above sea level. The climate is considerably warmer and wetter (875 mm rainfall per annum at Bega) than that of the Byadbo area.

In a recent Environmental Impact Statement (Forestry Commission of New South Wales, 1983), *A. silvestris* is described as being 'reasonably well distributed in Wandella State Forest right to the edge of the tableland . . . but only occasionally forms (these) thickets which exclude all but an occasional eucalypt emergent'. A map shows areas where *A. silvestris* canopy cover is 80% or more, and these are nearly all on north- or west-facing slopes and all on Ordovician metasediments. A comment is made that the 'species . . . is generally too moist to be burnt in hazard reduction burning operations'.

No mention is made in the document of *Eriostemon trachyphyllus* except in the general species list, but in the Silvestris Forest Preserve nearer Narooma it forms a dense understorey beneath small trees of *A. silvestris* (up to 15 m tall) and scattered eucalypts (up to 24 m tall). Similar scrubs have been reported in the Upper Brogo River catchment (M. Parris, Ben Boyd National Park Advisory Committee, pers. comm.), and the *A. binervia–E. trachyphyllus* dry scrub reported by Costin (1954) is located on the lower Maclaughlin River in a habitat intermediate to those on the Snowy and Brogo Rivers. All these scrubs are located on metasediments. The wide range of climate that the scrubs tolerate suggests that climate is not a major factor; soil type and fire regime remain the most likely influences controlling their present distribution.

Closer to the coast, *A. silvestris* is a common species of forest communities and it could be postulated that a dry scrub may develop on a dry slope with skeletal soils in response to frequent hot fires. If this frequency were too high to allow eucalypt regeneration, but not too high to prevent *Acacia* reproducing from seed, the seedlings of the latter may crowd out all other species. Indeed the lower Brogo River scrub was reported to have appeared after an intense wildfire, replacing forest (D. Christopher, New South Wales Forestry Commission, pers. comm.). It is not known whether this fire was the last of a series.

The absence of *A. silvestris* from surrounding vegetation in the Byadbo area suggests that the scrubs have been in existence for a long period. Furthermore, if the Byadbo scrubs had a similar origin to those in other localities, this suggests a much moister climate than exists at present.

Scrubs dominated by *A. silvestris* appear to be much more common and widespread than those dominated by *A. binervia*. It would thus be appropriate to place the *A. binervia–E. trachyphyllus* alliance of Costin (1954) in an association under a new *A. silvestris–E. trachyphyllus* alliance.

Conclusion

The Plan of Management for Kosciusko National Park (1982) includes the 'black scrubs' under 'Outstanding Natural Resources' and lists their protection as an objective of management (Section 1.3.3 of the Plan of Management).

The word 'protection' has many connotations, but if the objective is to maintain scrubs in a variety of age classes, then the plan should recognize that the natural cycle of regeneration of the scrubs almost certainly includes intense fire. It would appear that the only conceivable threat to the continued existence of the scrubs may come from attempts to exclude intense fire by too-frequent low-intensity burns in the surrounding woodland.

We suggest that a more appropriate name for the *Acacia binervia* (*glaucescens*)–*Eriostemon trachyphyllus* alliance of Costin (1954) would be the *A. silvestris–E. trachyphyllus* alliance. *A. silvestris–E. trachyphyllus, A. binervia–E. trachyphyllus, A. falciformis–E. trachyphyllus* and *A. kettlewelliae–E. trachyphyllus* would be associations within the alliance.

Acknowledgments

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Appendix 1
List of species collected in and around the Byadbo dry scrubs

Species	Within scrubs	Ecotone	Surrounding woodland
PTERIDOPHYTA			
Aspleniaceae			
Asplenium flabellifolium Cav.			X
Pteridaceae			
Cheilanthes tenuifolia Sw.	X	X	X
GYMNOSPERMAE			
Cupressaceae			
Callitris endlicheri (Parl.) F. M. Bailey			X
ANGIOSPERMAE-DICOTYLEDONEAE			
Casuarinaceae			
Allocasuarina verticillata (Lam.) L. Johnson (syn. *Casuarina stricta* Dryand.).	X		
Proteaceae			
Banksia marginata Cav.			X
Persoonia silvatica L. Johnson			X
Santalaceae			
Exocarpos cupressiformis Labill.	X		
Loranthaceae			
Amyema quandang (Lindl.) Tiegh.	X		
Polygonaceae			
Muehlenbeckia diclina (F. Muell.) Druce		X	
Chenopodiaceae			
Einadia hastata (R. Br.) A.J. Scott	X	X	X
Lauraceae			
Cassytha melantha R. Br.	X		
Ranunculaceae			
Clematis microphylla DC.			X
Mimosaceae			
Acacia dealbata Link		X	X
A. deanei (R.T. Baker) Welch *et al.* subsp. *paucijuga* Tind.			X
A. doratoxylon A. Cunn.	X		X
A. falciformis DC.	X	X	X
A. implexa Benth.	X		X
A. kettlewelliae Maiden	X	X	X
A. mearnsii De Wild.		X	X
A. silvestris Tind.	X		
Fabaceae			
Bossiaea buxifolia A. Cunn.			X
Daviesia mimosoides R.Br.	X		X
Glycine clandestina Wendl.			X
Indigofera australis Willd.		X	X
Oxylobium procumbens F. Muell.			X
Pultenaea procumbens A. Cunn.			X
P. juniperina Labill. var. *planifolia* H.B. Williamson			X
Rutaceae			
Crowea exalata F. Muell.		X	X
Eriostemon trachyphyllus F. Muell.	X		
Phebalium lamprophyllum (F. Muell.) Benth.	X	X	
Zieria cytisoides Sm.			X
Sapindaceae			
Dodonaea viscosa Jacq. subsp. *cuneata* J.G. West			X
D. viscosa Jacq. subsp. *spatulata* J.G. West	X	X	X
D. viscosa Jacq. subsp. *cuneata* J.G. West X subsp. *angustissima* J.G. West		X	

Species	Within scrubs	Ecotone	Surrounding woodland
Rhamnaceae			
Cryptandra amara Sm.			X
Pomaderris angustifolia N.A. Wakefield			X
P. ledifolia A. Cunn.			X
P. pallida N.A. Wakefield			X
Myrtaceae			
Callistemon pallidus (Bonpl.) DC.	X		
Eucalyptus albens Benth.	X		X
E. bridgesiana F. Muell.		X	X
E. dives Schau.	X	X	X
E. nortonii (Blakely) L. Johnson	X	X	X
E. macrorhyncha F. Muell. ex Benth.	X	X	X
E. melliodora A. Cunn. ex Schau.		X	X
E. viminalis Labill.		X	X
Leptospermum phylicoides (A. Cunn. ex Schau.) Cheel		X	
Araliaceae			
Polyscias sp. aff. *sambucifolia*	X	X	X
Apiaceae			
Platysace lanceolata (Labill.) Norman		X	
Epacridaceae			
Astroloma humifusum (Cav.) R.Br.			X
Lissanthe strigosa (Sm.) R.Br.		X	X
Melichrus urceolatus R.Br.			X
Monotoca scoparia (Sm.) R.Br.			X
Lamiaceae			
Prostanthera phylicifolia F. Muell.	X		
P. rotundifolia R.Br.			X
Solanaceae			
Solanum linearifolium I.I. Herasimenko		X	X
Goodeniaceae			
Goodenia ovata Sm.	X		X
Asteraceae			
Brachycome rigidula (DC.) G.L. Davis			X
Cassinia aculeata (Labill.) R.Br.			X
C. longifolia R.Br.			X
Cymbonotus sp.	X		X
Helichrysum conditum N.A. Wakefield		X	X
H. obcordatum (DC.) Benth.	X	X	
Olearia iodochroa (F. Muell.) F. Muell. ex Benth.	X	X	
O. phlogopappa (Labill.) DC.	X	X	X
Senecio hispidulus A. Rich.			X
MONOCOTYLEDONEAE			
Poaceae			
Bothriochloa macra (Steud.) S.T. Blake	X		
Chionochloa pallida (R.Br.) S.W.L. Jacobs	X	X	X
Xanthorrhoeaceae			
Xanthorrhoea australis R.Br.			X
Orchidaceae			
Diuris sulphurea R.Br.			X

Distribution and spread of the Alismataceae in the rice-growing region of New South Wales

S. McIntyre and M. R. Newnham

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Abstract

McIntyre[1], S. and Newnham[2], M. R. (CSIRO Centre for Irrigation Research, Griffith, Australia 2680) 1988. Distribution and spread of the Alismataceae in the rice-growing region of New South Wales. Cunninghamia 2(1): 25–38. — The distributions of five species of the Alismataceae are described for the rice-growing region of New South Wales. Two native species occur in the area: *Alisma plantago-aquatica* L. is uncommon, but *Damasonium minus* (R. Br.) Buch. is widespread in wetlands and extremely abundant in rice fields, where it is regarded as a major weed.

Irrigation development has enhanced the introduction and spread of aquatic plants and three members of the Alismataceae have entered the region in the last 20 to 30 years. Within the irrigation areas, the plants have dispersed along irrigation channels and all three have been recorded in rice fields. *Sagittaria montevidensis* Cham. *et* Schlecht. is already widespread in the study area but remains a relatively minor weed of rice. *Alisma lanceolatum* With., although still restricted in distribution, has developed extremely high population levels in rice. *Sagittaria graminea* Michx. is also restricted, but shows more potential as a weed of irrigation channels than of rice fields.

Introduction

The development of irrigation on the Riverine Plain in New South Wales has resulted in some major changes to the region. In the irrigated areas human settlement has greatly intensified and there has been a marked increase in the extent of aquatic habitats. Drainage and supply channels, roadside ditches, irrigated pasture and rice crops are examples of aquatic habitats that have been created in addition to, and have sometimes replaced, the natural wetlands.

Many species of the original wetlands and swamps have successfully colonised these new habitats. In addition, introduced aquatic species have entered the region, assisted by human activity.

The Alismataceae is a family of aquatic plants, represented in the region by five species. Two of these, *Alisma plantago-aquatica* L. and *Damasonium minus* (R. Br.) Buch. are native, and three species are introductions: *Alisma lanceolatum* With., *Sagittaria montevidensis* Cham. *et* Schlecht. and *Sagittaria graminea* Michx. All five species have been recorded in rice fields in the study area.

This paper documents the history of introduction and current distribution of the Alismataceae in the rice-growing areas of New South Wales. The three introduced species are still spreading and have not yet achieved their potential distribution. The information on these three species is presented in detail; it is hoped that this will permit useful documentation of the colonising process.

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Methods

Search strategies

The search areas included the Murrumbidgee, Coleambally and Tullakool Irrigation Areas (I.A.) and the Benerembah, Tabbita and Murray Valley Irrigation Districts (I.D.), a total of over one million hectares. Some additional aquatic habitats were also visited, notably those found in the riverine forests associated with the Murray and Murrumbidgee Rivers. Two alternative search strategies were used to locate the plants, the choice depending on the known abundance of each species..ch

Plants known to be restricted in occurrence. With such an extensive area under study, it was impractical to examine systematically the entire area in detail. Instead, searches radiated from known occurrences and were continued until it was evident that the whole local population had been delineated. Additional searching on a less intensive scale was then conducted over a large area surrounding the known infestations to pick up any satellite populations. This strategy was effective for delineating known occurrences but may have resulted in some isolated localised populations being missed.

Localised populations of restricted species were mapped in detail. These data, together with information from local people, provided evidence for determining possible modes of introduction and spread of the plants.

Plants known to be widely distributed. For widely occurring species, distributions were recorded as points on a map, each represented by a plant collection. Efforts were made to obtain an even spread of points over the entire area in which the species was known to occur.

Plant collections

Collections were made with the intention of fully representing the distribution of each species. Specimens were lodged at the National Herbarium of New South Wales (NSW). All collections were made from January to April 1985, with the exception of several *Sagittaria graminea* specimens which were collected in May 1984.

Where collections were made, local population numbers were estimated on the following scale:

<10	very low
10–100	low
100–1000	medium
1000–10 000	high
>10 000	extremely high

For most species, these values represented numbers of individual plants. An exception was the vegetatively reproducing *Sagittaria graminea*, for which population estimates represented numbers of visually identifiable ramets that look superficially like individual plants but may be joined underground.

Definition of terms

Irrigation channel. This term is used collectively to include supply and drainage channels.

Supply channel. An artificially constructed watercourse for the transport of water from the sources of supply (Murrumbidgee and Murray Rivers) to the farms in the Irrigation Areas and Districts. They are generally filled with water throughout the summer and vary in size depending on the location. Major supply channels are over 20 m wide, while on-farm channels are only a few metres wide.

Drainage channel. These may be natural or artificially constructed watercourses which remove excess water from irrigated land. They are generally shallower than supply channels of equivalent width.

Borrow pit. Flood irrigation is the most common watering method in the region and contour banks are constructed within paddocks to control water movement. When rice is grown, these form the boundary of the bays that remain flooded throughout the season. Borrow pits are narrow ditches that run parallel to the contour banks and are excavated when soil is 'borrowed' to form the bank. They assist in the drainage of water from the paddock and are not generally sown with rice. Consequently, they can provide an open flooded area for the establishment of aquatic plants.

Ditch. This refers to any narrow excavation designed for the collection of water, that is not directly associated with the drainage and supply of irrigation water.

Results and Discussion

Alisma species

Background. *Alisma lanceolatum* is native to Europe, North Africa and West Asia and has since been introduced to Canada, Chile (Häfliger *et al.* 1982) and Australia where it established at Creswick, Victoria some fifty years ago (Aston 1977). The only other collections of *A. lanceolatum* in Australia are from the Mt Lofty Ranges (S.A.), Woori Yallock (Vic.) and Echuca (Vic.). In 1983 it was collected from a rice crop in the Coleambally Irrigation Area, the first record of this species in New South Wales.

Alisma lanceolatum is a principal weed of rice in Southern Europe (Catizone 1981). Barrett and Seaman (1980) also record it for Californian rice fields, where it is rare and not considered to be of importance. Predicting how troublesome *A. lanceolatum* will become in Australian rice fields is guesswork, but the nature and extent of the original infestation in rice suggests that it may be a problem.

Established populations of *A. lanceolatum* were found in the central Coleambally Irrigation Area and the Deniboota Irrigation District, and these are described in detail. The plant was also found in large numbers in drainage channels and roadside ditches in dairying land around Echuca township (Figure 1). These three occurrences are almost certainly disjunct, but it is possible that some isolated populations remain unrecorded in the intervening areas. The method of dispersal and source of material introduced to each of the three sites is unknown, however evidence suggests that the Coleambally and Deniboota infestations originated from separate, long-distance dispersal events.

A second *Alisma* species, *A. plantago-aquatica*, is native to the area but is rare (Figure 1). Although a common rice weed in Brazil, Chile (Gonzalez, Garcia & Perdomo 1983) and in eastern Europe (Podkin, Chanukvadze & Frolova 1983), *A. plantago-aquatica* has been found only as a few plants in two rice crops in New South Wales and is not considered to be a potential threat under current conditions of rice husbandry.

Distribution of *Alisma lanceolatum* in the Coleambally Irrigation Area. The extent of the first population discovered in 1983 was mapped in detail and twelve farms were found to have been colonised by *A. lanceolatum*. Eighteen rice crops were infested to varying degrees and populations were also found in two drainage channels associated with the affected farms. This information is summarised in Figure 2 and Table 1.

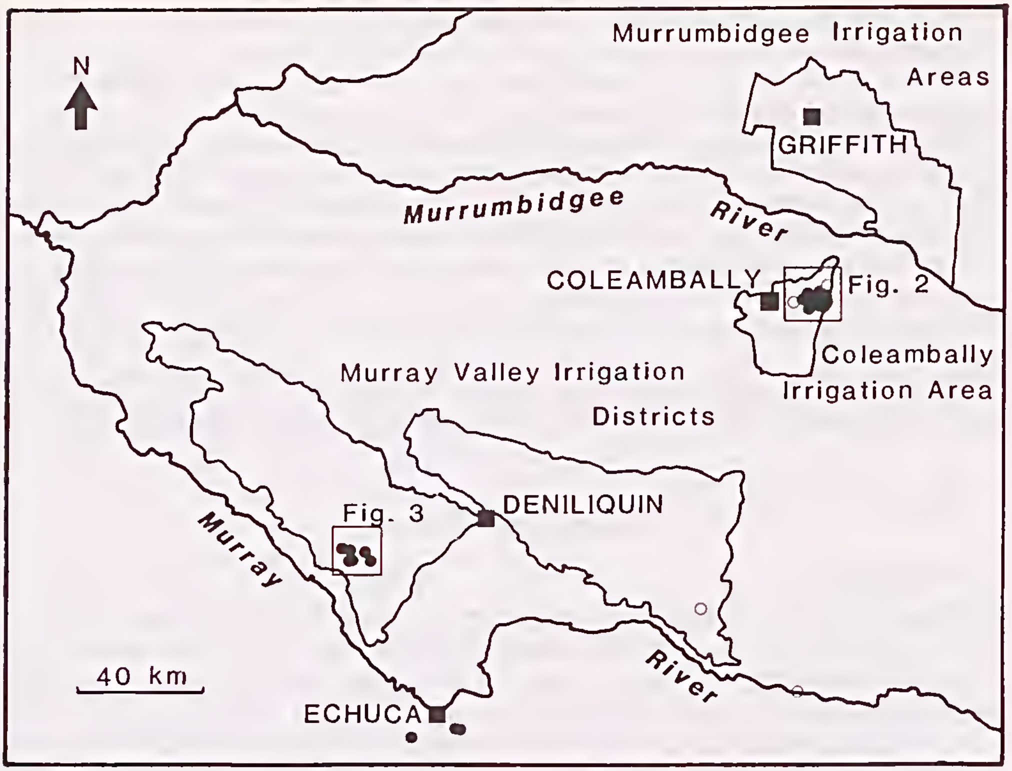
Murrumbidgee Irrigation Areas
GRIFFITH
N
Murrumbidgee River
COLEAMBALLY
Fig. 2
Coleambally Irrigation Area
Murray Valley Irrigation Districts
DENILIQUIN
Fig. 3
Murray River
40 km
ECHUCA

Figure 1. Distribution of *Alisma* spp. in the rice-growing areas of New South Wales, showing locations of collections of *A. lanceolatum* (●) and *A. plantago-aquatica* (○), January to March 1985.

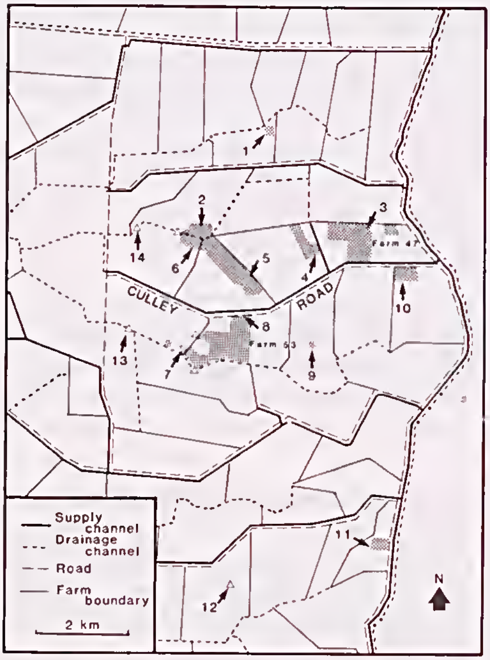

Figure 2. Distribution of *Alisma lanceolatum* in the Coleambally Irrigation Area, showing areas under rice where *A. lanceolatum* occurred (▨), locations of irrigation channel populations (△) and locations of collections (1–14) referred to in Table 1.

Table 1: Details of collections of *Alisma lanceolatum* from the Coleambally Irrigation Area, January to February 1985 (see Figure 2).

Map location number	Collection number	Habitat	Farm number	Population size (number of plants)	Comments
1	MNSM 366	rice crop	30	100–1000	throughout one bay
2	MNSM 358	rice crop	44	10–100	scattered through bay
3	MNSM 350	rice crop	47	1000–10 000	restricted mainly to borrow pits
4	MNSM 355	rice crop	48	100–1000	throughout bays
5	MNSM 356	rice crop	49	100–1000	throughout bays; spread to farm supply
6	MNSM 357	rice crop	50	100–1000	throughout bays
7	MNSM 361	rice crop	52	10–100	in borrow pits of four bays
8	MNSM 339	rice crop	53	>10 000	very severe infestation throughout
8	MNSM 348	rice crop	53	1000–10 000	severe infestation throughout
8	MNSM 338	on-farm supply channel	53	10–100	adjacent paddock infested but fallow
9	MNSM 360	rice crop	54	<10	in borrow pit, two small plants
10	MNSM 340	rice crop	56	100–1000	in crop and adjacent wet, fallow bay
11	MNSM 365	rice crop	96	10–100	throughout crop
12	MNSM 501	on-farm supply channel	99	<10	near uninfested crop
13	MNSM 346	drainage channel	—	<10	—
14	MNSM 352	drainage channel	—	10–100	—

The original infestation is thought to have been on Farm 47 or 53. Both properties were previously owned by the same person and now support considerable populations of *A. lanceolatum*, the largest in the area. There is no evidence of plants growing in supply channels leading to the infested area, suggesting that these farms support the founding population in the Coleambally I.A. The on-farm supply channels that did contain *A. lanceolatum* appear to have been colonised from populations in nearby rice crops. The rash of smaller infestations around these larger populations also appear to have arisen from short-distance dispersal.

Three occurrences of *A. lanceolatum* occur some distance away from the main infestation (Figure 2, sites 1, 11 and 12) and cannot be explained in terms of short-distance dispersal. In all three cases the use of agricultural machinery is strongly implicated in the spread of *A. lanceolatum*. Machinery from heavily infested farms has at some time been used on the land where the three satellite infestations occurred.

In addition to farm machinery, a likely cause of spread of *A. lanceolatum* in the future is the system of drainage channels leaving the affected area. These channels supported a small number of plants (<100) but they were large, well established and prolific producers of seed, which is readily carried downstream. At least one rice crop infestation (Figure 2, site 2) appears to have resulted from dispersal from an infested drainage channel.

***Alisma lanceolatum* in the Deniboota Irrigation District.** The infestation mapped in the Deniboota district was centred approximately 5 km south of Caldwell (Figure 3). Populations were discovered in two ditches, a rice crop and the associated drainage system (Table 2). The area between these locations and the nearest known *A. lanceolatum* at Echuca (40 km southeast) was searched, but no plants were found and it was clear that the Caldwell and Echuca infestations were disjunct.

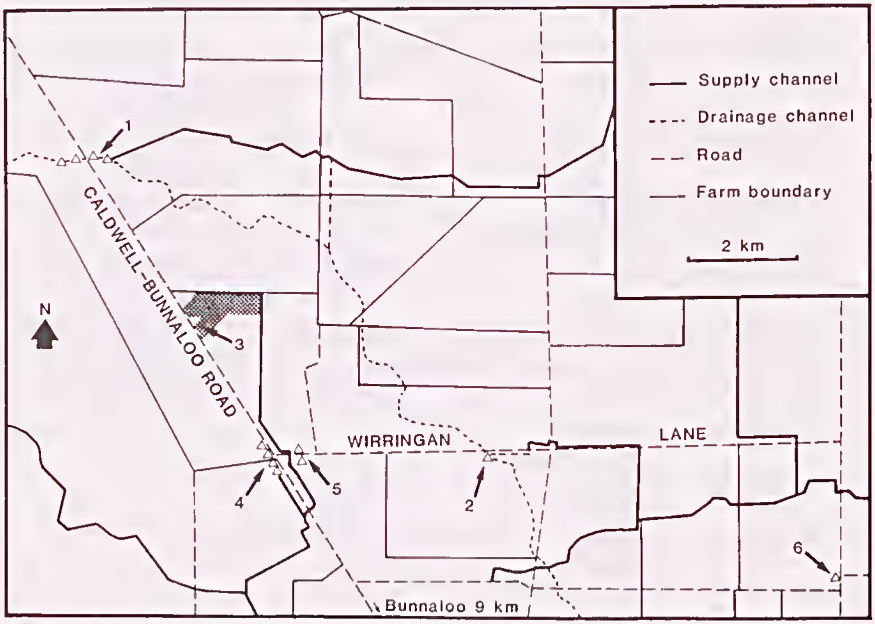

Figure 3. Distribution of *Alisma lanceolatum* in the Deniboota Irrigation District showing extent of populations in rice (▨), locations of populations in ditches and irrigation channels (△) and locations of collections (1–6) referred to in Table 2.

Although the six Caldwell populations are all likely to have arisen from one instance of long-distance dispersal (from Echuca, Coleambally or elsewhere), the founding population could not be identified. The largest infestation occurred in the affected rice crop, but here the large numbers of plants could have been a reflection of the extent of suitable habitat as much as an indicator of infestation age. Rice crops in this area are much more widely separated than in the Coleambally area, where rice fields are in close proximity. The fact that plants were found a considerable distance upstream of the infested crop, in the associated Deniboota Escape Channel, suggests that the rice field does not support the founding population.

The *A. lanceolatum* populations at Caldwell were isolated and scattered in comparison with the Coleambally distribution. The Caldwell infestation did not appear to be spreading on a front; future expansion is dependent on chance events and could occur in any direction. The only predictable direction of spread is downstream from existing populations growing in the Deniboota Escape Channel.

The scattered distribution of *A. lanceolatum* appears to be related to the low intensity of irrigation development in the Deniboota Irrigation District and the associated low density of suitable wet habitats. This situation, which is in contrast to that in the Coleambally area, is probably responsible for the lower number of affected rice crops in the Caldwell area (1 compared with 18 in the Coleambally I.A.). Given present land use in the Deniboota I.D., the rate of spread of *A. lanceolatum* amongst rice crops is likely to be slower than in Coleambally.

Table 2: Location, size and habitat of all populations of *Alisma lanceolatum* mapped in the Deniboota Irrigation District, January to March 1985 (see Figure 3).

Map location number	Collection number	Habitat	Population size (number of plants)	Comments
1	MNSM 515	drainage channel	10–100	downstream from infested rice crop
2	MNSM 520	drainage channel	1	upstream from infested rice crop
3	MNSM 517	rice crop	>10 000	growing throughout an aerially sown crop
4	MNSM 518	railway ditch	100–1000	area subject to foot traffic; seasonally wet
5	MNSM 519	roadside ditch	100–1000	growing with *Typha*
6	MNSM 521	intermittent watercourse	10–100	drains into Deniboota Escape (sites 1 & 2)

Sagittaria species

Sagittaria montevidensis

Sagittaria montevidensis is a native of North and South America where it is a weed of rice in California (Barrett & Seaman 1980) and Brazil and Uruguay (Gonzalez *et al.* 1981). Two subspecies have been introduced to Australia, ssp. *calycina* and ssp. *montevidensis*. Both are cultivated as ornamentals and the latter was recorded in Sydney in 1926 (Aston 1977; Sainty & Jacobs 1981). Subspecies *calycina* was first recorded in the Murrumbidgee Irrigation Area in 1962 and has spread rapidly in irrigation channels and rice fields. Although both subspecies are recorded for the Murrumbidgee I.A., it appears that only one, ssp. *calycina*, is widespread and ssp. *montevidensis* was not found in the region. The widespread Californian weed is also referable to ssp. *calycina* and has an annual life cycle. There are also reports of *S. sagittifolia* L. from the Griffith-Leeton district, but they are considered by Aston (1977) to be the result of confusion with *S. montevidensis*.

Since its introduction, *S. montevidensis* has spread southwards and is now also well established in the Coleambally I.A. (Figure 4). It occurs most frequently in drainage channels and rice crops. Recently, an isolated infestation was reported in the Tullakool I.A. This recording was the cause of some concern as it is the first known occurrence of this plant in the Murray Valley region.

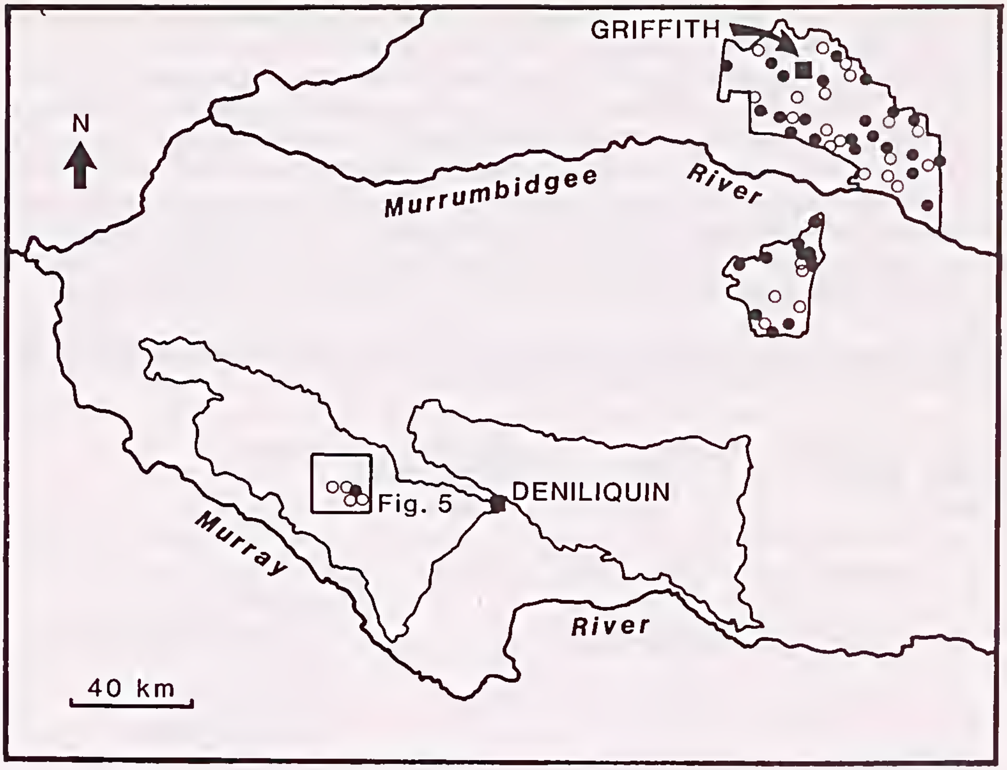

Figure 4. Distribution of *Sagittaria montevidensis* in the rice-growing areas of New South Wales, showing locations of collections from rice crops (●) and irrigation channels (○), 1984–85.

Table 3: Details of collections of *Sagittaria montevidensis* from the Tullakool Irrigation Area, January 1985 (see Figure 5).

Map location number	Collection number	Habitat	Population size (number of plants)	Comments
1	MNSM 418	drainage channel	1000–10 000	drainage from original infestation
2	MNSM 419	rice crop	10–100	3 bays affected along edge adjoining infested channel
3	MNSM 422	drainage channel	<10	flowing west along Burraboi Road
4	MNSM 423	drainage channel	10–100	in Niemur Drain at junction of Burraboi & Tullakool-Moulamein Rds
5	MNSM 424	drainage channel	10–100	tributary of Niemur Drain flowing west, bordering saltworks

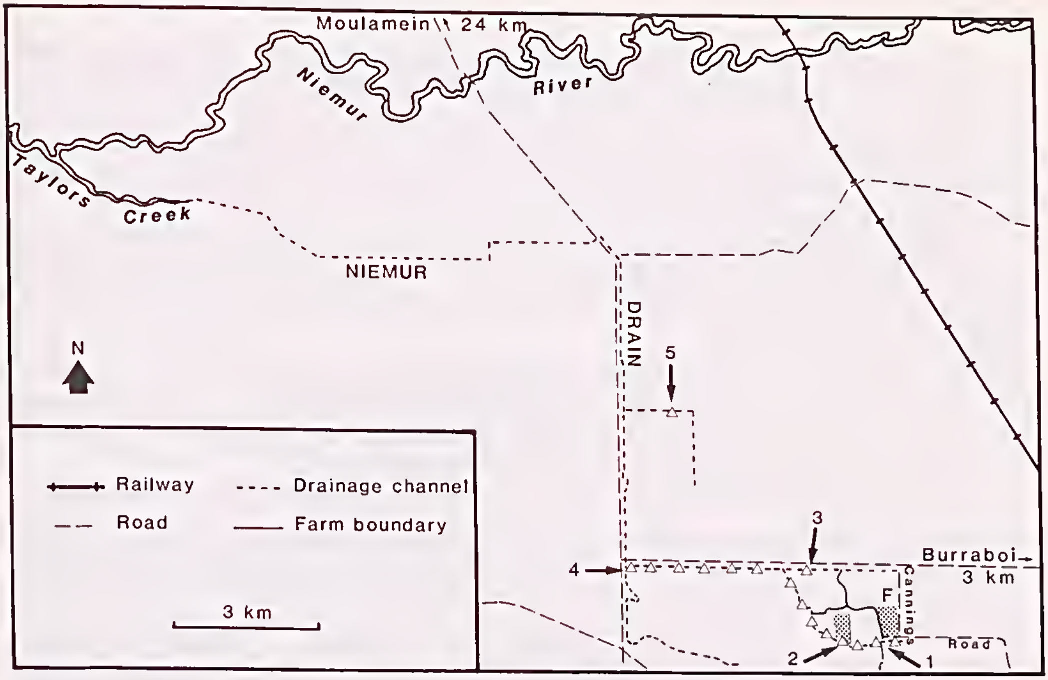

Figure 5. Distribution of *Sagittaria montevidensis* in the Tullakool Irrigation Area, showing extent of irrigation channel populations (△), locations of infested rice crops (▨) and collections (1–5) referred to in Table 3. F = field fallow in 1984–85.

***Sagittaria montevidensis* in the Tullakool Irrigation Area.** An infestation was reported in a rice crop in the Tullakool I.A. in the 1983–84 season. According to the grower, this introduction was the result of sowing contaminated seed. The seed used was from the Murrumbidgee I.A.

The site of the original infestation was fallow at the time of the survey, but *S. montevidensis* had spread into the associated drainage system and this area was mapped (Figure 5, Table 3). The extent of this infestation suggests that the original plants must have been introduced some years ago. *Sagittaria montevidensis* was found to occur sporadically along a 7 km stretch of drainage channel. The Water Resources Commission reported that a further 17.5 km of the Niemur Drain, as far as Taylors Creek, had been colonised but a vigorous spraying program has removed all evidence of these plants.

One rice crop adjacent to the infested channel was found to contain *S. montevidensis*. In this field, three bays were infested and plants were restricted to small clumps at the edge near the channel, suggesting that short-distance dispersal from the channel had occurred.

The introduction of *S. montevidensis* to the Murray Valley was probably inevitable, given the degree of population build-up in the northern irrigation areas. As suggested for *Alisma lanceolatum*, the rate of spread of *S. montevidensis* through the southern irrigation districts is likely to be slower than in irrigation areas, owing to the lower density of aquatic habitats.

Sagittaria graminea

A native of North America, *Sagittaria graminea* was introduced to Australia in the late 1950s and is now naturalised in Queensland, New South Wales and Victoria (Aston 1977). It is regarded as a troublesome weed in north-central Victoria where it obstructs water flow in drainage channels and creeks (Sainty & Jacobs 1981). *Sagittaria graminea* does not appear to be a significant rice weed elsewhere in the world.

Within the rice growing region, *S. graminea* is currently restricted to the Murray Valley where it seems to have entered as two separate introductions, both occurring as disjunct populations in the Berriquin Irrigation District (Figure 6). These are described below.

***Sagittaria graminea* in the Mulwala Canal.** *Sagittaria graminea* appears to have entered New South Wales from north-central Victoria via the Mulwala Canal which flows away from Lake Mulwala on the Murray River (Figure 7, Table 4). This canal is the main supply channel for the Berriquin I.D.

Lake Mulwala itself had been colonised by *S. graminea* and a 30 km stretch of the canal supported sporadic populations. Establishment was restricted to the canal banks where the water was shallow and slow-flowing. Intensive application of herbicides by the Water Resources Commission had limited the extent of the canal populations. Several branch supply channels were infested but plants have since been eradicated. Spot checking of rice crops and channels throughout the district indicated that no populations appeared to have arisen from the canal infestation. The chance of this happening in the future is probably high, but at present the infection pressure is limited as the number of plants in Mulwala Canal is low.

The 'Lindifferon' infestation. Large numbers of *S. graminea* were found on three adjacent holdings in the Berriquin I.D. near Deniliquin (Figure 8, Table 4). This population is over 40 km away from the Mulwala Canal populations.

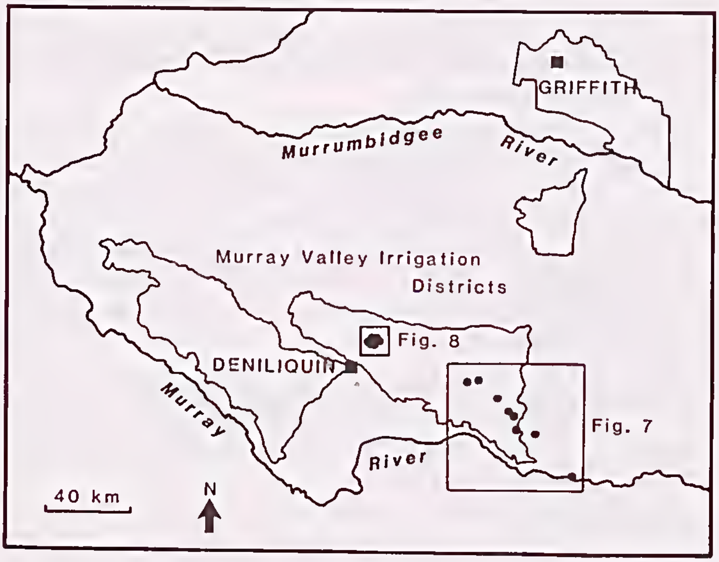

Figure 6. Distribution of *Sagittaria graminea* in the rice-growing areas of New South Wales showing locations of collection sites (●).

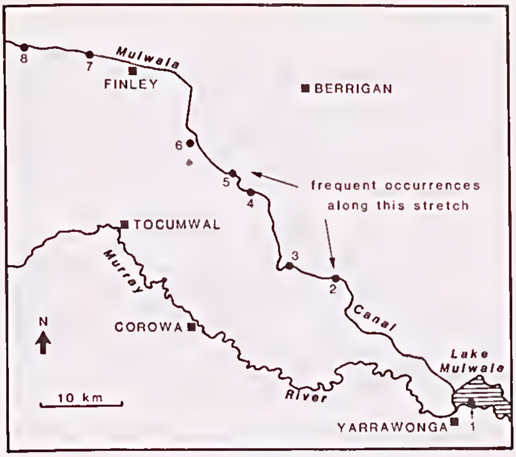

Figure 7. Distribution of *Sagittaria graminea* in the Berriquin Irrigation District, where it has colonized Mulwala Canal from a population in Lake Mulwala. Numbers (1–8) show locations of collections referred to in Table 4.

Table 4: Details of collections of *Sagittaria graminea* from the Berriquin Irrigation District, February to March 1985 (see Figures 7 & 8).

Map location number	Collection number	Habitat	Population size (number of plants)	Comments
1	MNSM 508	Lake Mulwala	10–100	much larger population (>1000 plants) near this collection
2	MNSM 576	Mulwala Canal	<10	broad-leaved plants growing in shade
3	MNSM 506	Mulwala Canal	1000–10 000	restricted to edge of canal which is very deep and wide
4	MNSM 510	Mulwala Canal	100–1000	as for 3
5	MNSM 511	Mulwala Canal	10–100	as for 3
6	MNSM 512	supply channel	10–100	close to point of departure from canal
7	MNSM 513	Mulwala Canal	10–100	as for 3
8	MNSM 514	supply channel	100–1000	50 m downstream from point of departure from canal
9	SM 1002*	supply channel	100–1000	growing throughout channel
10	SM 1003*	rice crop	1000–10 000	population extended to 3 adjoining rice crops
11	MNSM 586	supply channel	100–1000	broad-leaved plants growing in shade
12	MNSM 587	supply channel	100–1000	narrow-leaved plants growing in full sun
13	MNSM 590	supply channel	100–1000	growing throughout channel
14	MNSM 591	supply channel	100–1000	growing throughout channel
15	MNSM 592	rice crop	<10	restricted to borrow pit

* SM 1002 and SM 1003 were assessed for population size in 1985 but collected in May 1984.

On the property 'Lindifferon', a dam near an abandoned farmhouse supports large numbers (1000–10 000 plants) of *S. graminea*. The evidence available, including communications with farmers and the distribution pattern of the weed, indicates that the dam holds the founding population of *S. graminea*. It seems likely that the plant was introduced to the dam as an ornamental many years ago. Two adjacent properties, 'Box Lea' and 'Carmarthan', also support large populations.

On 'Lindifferon', *S. graminea* was limited to the dam, a rice crop and the supply channel between the dam and the crop. The rice crop on 'Box Lea' appeared to be free of the weed, although it grew in the farm supply channels. The third property, 'Carmarthan', was more seriously affected, with *S. graminea* growing in three rice crops and most of the supply channels. In the rice crops *S. graminea* was generally restricted to the borrow pits and areas of low rice plant density.

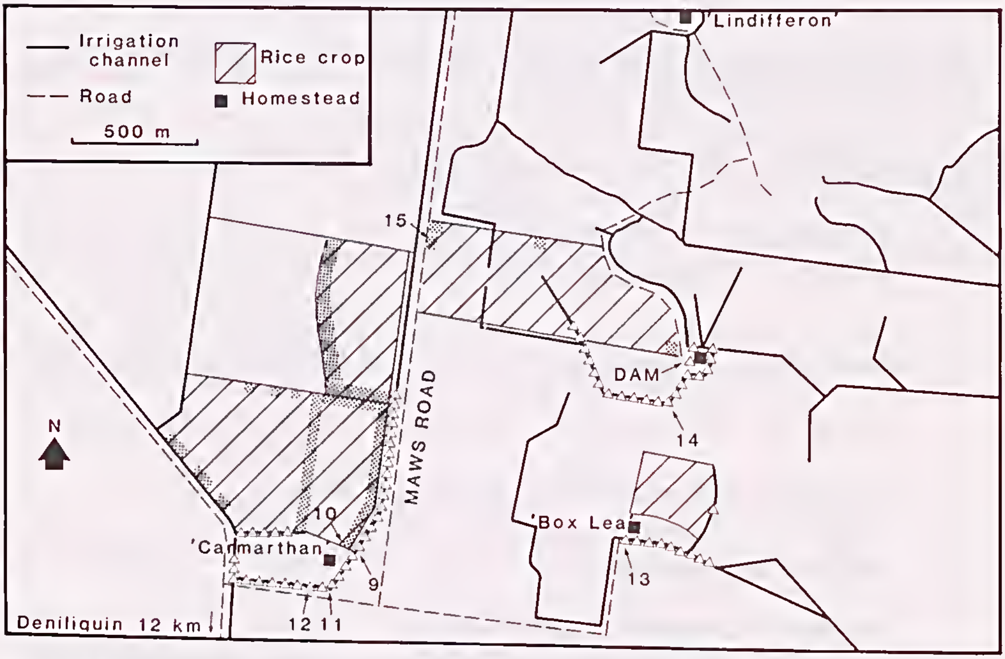

Figure 8. Distribution of *Sagittaria graminea* in the Berriquin Irrigation District, showing locations of populations in rice crops (▨), irrigation channels (△) and locations of collections (9–15) referred to in Table 4.

Damasonium minus

Damasonium minus is an annual plant which is endemic to Australia, where it is the most significant rice weed amongst the Alismataceae. The plant is widespread, but not particularly abundant in natural and seminatural wetlands (S. McIntyre, unpublished data). Plant numbers appear to have built up considerably in rice fields and *D. minus* began to be recognized as an important weed in the 1960s (Swain 1973), some 40 years after rice growing began.

Damasonium minus is widespread in all rice-growing districts; it was recorded at over 70% of sites in a survey of rice fields (McIntyre & Barrett 1985). Because of its abundance, no attempt was made to map *D. minus* and it can be considered ubiquitous in rice crops throughout the study area.

General Discussion

Several features of irrigation development ensure the spread of aquatic species. Plants are readily dispersed by water along the system of channels and spread efficiently over large areas. The movement of farm machinery and vehicles distributes soil, which may contain seed. These two methods appear to be the major dispersal mechanisms within irrigated areas.

Together, these factors make control of undesirable species difficult. Intensive herbicide programs such as those used against *Sagittaria graminea* in the Mulwala Canal and *Sagittaria montevidensis* in the Deniboota district have failed to eradicate these species. Eradication programs can probably only be successful for very small, isolated populations. As no systematic monitoring of weed populations occurs, introductions are often well established by the time they are noticed. Even rigorous monitoring could only be expected to reduce, not prevent, the establishment of new alien aquatic plants in the future.

Members of the Alismataceae have generally benefited from irrigation development. They are most abundant in drainage channels, rice crops and, to a lesser extent, in supply channels, wherever shallow water stands for prolonged periods. They do not often grow in transient wetland habitats such as roadsides and ditches.

The five species showed differing abilities to grow in various habitats. The newly introduced species may not yet have reached their potential range, but there are also differences in ecological characteristics.

Two of the five species appear to be serious competitors in rice crops. *Damasonium minus* is already a widespread, abundant weed, and *Alisma lanceolatum* has developed extremely high population levels within its current range. Interestingly, these species are the only ones to be recorded in ditches or roadsides and may be better adapted to intermittent flooding and high levels of disturbance.

Although widespread, *Sagittaria montevidensis* is not a particularly abundant rice weed in New South Wales, and tends to be restricted to borrow pits on the edge of rice bays. This is in contrast to the situation in California, where it is the most abundant weed of rice (Barrett & Seaman 1980). Such a discrepancy may be related to differences in land use patterns. Unlike *Alisma lanceolatum* and *Damasonium minus*, *S. montevidensis* has poorly developed seed dormancy (B. Cox, unpublished data) that prevents the accumulation of large reserves of viable seed in the soil. In situations where fields are continuously cropped, as is common in California, this characteristic is not a disadvantage because seed populations can be replenished annually. However, these plants would be vulnerable in New South Wales, where crop rotation is usually practised. Under these conditions, annual plants require a bank of dormant seed to survive fallow periods that are unfavourable to plant growth.

The comparative rarity of *Alisma plantago-aquatica* in the rice-growing region can not be explained. Its insignificance as a rice weed is also difficult to account for, especially in view of its importance in rice fields of Brazil, Chile and Europe.

Acknowledgments

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Catizone, P. (1981). Farmers' weed control technology in rice in southern Europe. In *Weed control in rice* (International Rice Research Institute), pp. 183–191. IRRI, Los Baños, Philippines.

Gonzalez, J., Garcia, E., & Perdomo, M. (1981). Important rice weeds in Latin America. In *Weed control in rice* (International Rice Research Institute), pp. 119–132. IRRI, Los Baños, Philippines.

Häfliger, E., Kühn, U., Hämet-Ahti, L., Cook, C. D. K., Faden, R., & Speta, F. (1982). *Monocot weeds 3.* CIBA-GEIGY, Basle, Switzerland.

McIntyre, S., & Barrett, S. C. H. (1985). A comparison of weed communities of rice in Australia and California. *Proceedings of the Ecological Society of Australia* 14: 237–250.

Podkin, O.V., Chanukvadze, R. G., & Frolova, V. S. (1981). Farmers' weed control technology for water-seeded rice in Eastern Europe. In *Weed control in rice* (International Rice Research Institute), pp. 179–181. IRRI, Los Baños, Philippines.

Sainty, G.R., & Jacobs, S. W. L. (1981). *Waterplants of New South Wales.* New South Wales Water Resources Commission, New South Wales.

Swain, D. J. (1973). Weeds and weed control in rice in New South Wales, Australia. In *Proceedings of the 4th Asian-Pacific Weed Science Society Conference*, pp. 134–139. Rotorua, New Zealand.

Floristic lists of New South Wales (III)

D. A. Keith

(Accepted for publication 24.10.1986)

Abstract

Keith, D.A. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1988. Floristic lists of New South Wales (III). Cunninghamia 2(1): 39–73.* — A further two hundred and nineteen floristic lists, mainly from the 1981–85 period, have been collated with notes on the locality, arrangement of species and ecological information. The papers are numbered and ordered according to the botanical subdivisions of New South Wales, authors and dates of compilation.

Introduction

Floristic lists are often the only source of botanical information for a particular area and may serve as a useful starting point for more detailed study. Such lists may be used for general comparisons of the vegetation of different localities, or that of the same locality at different times. The preparation of an increasing number of environmental impact studies and plans of management in recent years has prompted a corresponding interest in floristic lists. This, the third bibliography compiled by the Royal Botanic Gardens, follows the works of Pickard (1972) and Bryant & Benson (1981).

Types of lists included

Similar criteria to those of Pickard (1972) and Bryant & Benson (1981) have been adopted and the journals listed by Bryant & Benson (1981) have been scanned. Most lists are from the 1981–85 period, though a number of older, previously overlooked, lists have been included. The lists range from regional floras to brief lists of predominating species and may or may not include ecological notes on the vegetation, the environment or the abundance of the species. They also vary considerably with regard to the size of the area surveyed and the precision with which this is defined, as well as completeness and the reliability of identifications. Nomenclature may be out of date depending on when the lists were compiled.

The bibliography includes both published and unpublished lists, copies of the latter are held at the Royal Botanic Gardens Library and are available on request from the libarian.

Arrangement of the Bibliography

Unlike the earlier bibliographies, the lists are here arranged according to the botanical subdivision in which they occur. A map of the botanical subdivisions of New South Wales is provided in the end papers. These are explained in full by Anderson (1961). Where a list covers more than one botanical subdivision it is listed under the major subdivision and cross-referenced in other relevant subdivisions. Within the subdivisions the lists are arranged alphabetically by author and then by date. The new arangement is intended to facilitate searching by the geographical area of interest. In this respect it is less cumbersome than the index system used by Pickard (1972) and Bryant & Benson (1981). As a further aid, the name(s) of the relevant 1:250 000 map sheet(s) are given at the end of each reference.

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* Present Address: National Parks and Wildlife Service, P.O. Box 1967, Hurstville, Australia 2220.

The order of the subdivisions is Lord Howe Island (refs 150–155), North Coast (156–188), Central Coast (189–291), South Coast (292–298), Northern Tablelands (299–302), Central Tablelands (303–319), Southern Tablelands (320–337), North Western Slopes (338–340), Central Western Slopes (341–350), South Western Slopes (351–352), North Western Plains (353–356), South Western Plains, North Far Western Plains (357–360), South Far Western Plains (361–363), New South Wales–General (364–369). The numbering of references follows on from Bryant & Benson (1981).

Each entry in the Bibliography is listed with its author, its date of publication (or compilation if unpublished) and its title. Annotations include the approximate number of species, their arrangement in the list and references to any ecological notes provided on abundance, habitat, soil type, plant communities, etc.

Discussion

The number of floristic lists in the current bibliography when compared with the earlier bibliographies of Pickard (1972) and Bryant & Benson (1981) (Table 1), shows that the annual rate of accumulation of lists is increasing (182 were collected in the 9 years between the first two bibliographies and a further 219 in the five years since the second).

The proportions of lists for the various botanical subdivisions (Table 1) show, apart from an increase in the percentage from the Central Coast since 1972, a decrease in numbers from the Western Slopes and Plains and little change for the

Table 1: Percentage of floristic lists for each of the botanical subdivisions of N.S.W. Data from Pickard (1972), Bryant & Benson (1981) and this paper.

	1972	1981	1985
Lord Howe Island	2	1	3
North Coast	16	16	15
Central Coast	24	35	47
South Coast	1	3	3
Northern Tablelands	8	4	2
Central Tablelands	9	6	8
Southern Tablelands	9	6	8
North Western Slopes	5	4	1
Central Western Slopes	6	5	5
South Western Slopes	3	1	1
North Western Plains	7	4	2
South Western Plains		2	0
North Far Western Plains	3	4	2
South Far Western Plains		5	1
New South Wales — General	5	3	3
TOTAL %	98	99	101
Total number of lists	290	182	219

other subdivisions. While this reflects the booming interest in Sydney's urban bushland, it is a disappointing trend given the very low numbers of lists presently available for other subdivisions, particularly on the Western Slopes and Plains, the Northern Tablelands and the South Coast.

With the increasing availability of computer data banks, the ability to integrate species list data is an important consideration to managers of natural areas. In compiling lists for such purposes, accurate identifications and site localities are essential. Long, unannotated lists covering large, poorly defined areas are less useful. Such lists should be recorded either by sites or by plant communities and should be accompanied, where possible, by descriptions of the relevant plant communities. Data on the relative abundance of the different species may also be worthwhile.

General References

Anderson, R. H. (1961). Flora of New South Wales. Introduction. *Contr. New South Wales Natl. Herb. Flora Series*, Nos 1–18: 1–15.

Bryant, H. J., & Benson, D. H. (1981). Recent floristic lists of New South Wales. *Cunninghamia* 1: 59–77.

Pickard, J. (1972). Annotated bibliography of floristic lists of New South Wales. *Contr. New South Wales Natl. Herb.* 4: 291–317.

Floristic Lists of New South Wales (III)

LORD HOWE ISLAND

150 Pickard, J. (1983). Vegetation of Lord Howe Island. *Cunninghamia* 1: 133–266.

Twenty-five associations in 20 alliances and 14 subformations are mapped at 1:15 840 and described using a novel tabular format. A key to associations is presented. Descriptions include comments on physiography, geology, structure, floristics and disturbance. Vegetation map.

LORD HOWE ISLAND

151 Pickard, J. (1983). Rare or threatened vascular plants of Lord Howe Island. *Biological Conservation* 27: 125–139.

A checklist of 60 species arranged alphabetically by genera under flowering plants and ferns with information on abundance, conservation status and distribution. Text discusses the rarity and threatened status of Lord Howe Island's flora.

LORD HOWE ISLAND

152 Pickard, J. (1984). Exotic plants on Lord Howe Island: distribution in space and time, 1853–1981. *Journal of Biogeography* 11: 181–208.

A checklist of 175 exotic species arranged alphabetically by families and genera within the major plant groups, with information on growth form, first record, continued presence and mode of introduction. Text discusses spatial patterns and temporal trends in weed invasion.

LORD HOWE ISLAND

153 Ramsay, H. P. (1984). The mosses of Lord Howe Island. *Telopea* 2: 549–558.

A checklist of 105 species with distribution information. Families and genera arranged in systematic order, species arranged alphabetically.

LORD HOWE ISLAND

154 Rodd, A. N., & Pickard, J. (1983). Census of vascular flora of Lord Howe Island. *Cunninghamia* 1: 269–280.
List of 379 species, arranged within the major plant groups alphabetically by families and genera with full synonymy and an index to common names. Separate lists are given for native and naturalized species and 33 previously recorded species have been deleted. Endemic species and genera are marked.
LORD HOWE ISLAND

155 Hutton, I. (1984). Vegetation survey report for the site of the proposed wind powered generator on Lord Howe Island. Energy Authority of New South Wales. (Unpub.).
Forty species are listed alphabetically by genus in Appendix 2. Naturalized, non-native and endemic species are annotated. Growth form and some common names are given.
LORD HOWE ISLAND

NORTH COAST

156 Anon. (undated). Kendall Management Area — plant species list. Forestry Commission of New South Wales. (Unpub.).
Checklist of 417 species listed alphabetically by families and genera with information on distribution ranges, habits, habitats, conservation status and localities.
HASTINGS

157 Adam, P. (1985). Species recorded from the Forbes River Crossing and Racecourse areas, Werrikimbee National Park. (Unpub.).
A checklist of 90 species arranged alphabetically by families with authorities and locality records.
HASTINGS

158 Atkinson, G., Hutchings, P., Johnson, M., Johnson, W. D., & Melville, M. D. (1981). An ecological investigation of the Myall Lakes Region. *Aust. J. Ecol.* 6: 299–327.
Aquatic and terrestrial vegetation. Forty-five species listed from 15 sites. Species also mentioned in text.
NEWCASTLE

159 Bartrim, G. (1980). Plant species occurring on the proposed Pipe Clay Creek Nature Reserve excluding Schnapper Island. In Flora & fauna survey of the proposed Pipe Clay Creek Nature Reserve excluding Schnapper Island. (Unpub.).
Checklist of 117 species, the families and genera arranged alphabetically within the major plant groups with common names, habitat, habit and abundance information. Location map. See ref. 176 (Floyd, 1980).
HASTINGS

160 Blakely, W. E., & Shiress, A. W. C. (1922). Flora of Ramornie. (Unpub.).
Checklist of 440 species. Compiled by J. Pickard (1974) from an annotated copy of Maiden & Betche (1916) *Census of New South Wales plants*.
GRAFTON

161 Coveny, R. (1981). Floristic list for Hat Head National Park, east of Kempsey. (Unpub.).
A checklist of 201 species listed in alphabetical order by genus.
HASTINGS

162 de Castro Lopo, L. (1981). *Plant communities of the Booti-Booti State Recreation Area*. Research Papers in Geography. No. 25. (University of Newcastle: Newcastle).

Five hundred and ninety-six species are recorded in families under major plant group headings; 24 vegetation types are described for six landform units. Vegetation map.

NEWCASTLE

163 Floyd, A. (undated). Sea Acres Wildlife Refuge. (Unpub.).

Brief descriptions of vegetation communities on exposed seaward slopes including physiography, dominant species, species diversity and number of tree species. (Near Port Macquarie). See ref. 164 (Floyd, 1961, 1976 & 1979).

HASTINGS

164 Floyd, A. (1961, 1976 & 1979). Vegetation description and plant species listing for Sea Acres Wildlife Refuge, Port Macquarie. Appendix A of the Classification Card for the Port Macquarie Coastal Conservation Area, National Trust of Australia (NSW). (Unpub.).

Checklist of 171 species arranged by family and genus within growth form types. Common names are given and introduced species marked, accompanied by brief description of habitat types. See ref. 163 (Floyd, undated).

HASTINGS

165 Floyd, A. (1969a). Forests of the Tweed Valley — Mt Warning. University of New England. (Unpub.).

A checklist of 104 species, the genera listed alphabetically within systematically arranged families for each community-type. Includes common names and abundance information. Additional species recorded by Floyd & Coveny (1977) (referenced in Bryant & Benson, 1981).

TWEED HEADS

166 Floyd, A. (1969b). Forests of the Tweed Valley — history and origin of the Tweed. University of New England. (Unpub.).

An account of the geological events of the last 135 million years (Cretaceous to recent) and their influence on the vegetation of the region.

TWEED HEADS

167 Floyd, A. (1969c). Forests of the Tweed Valley — plants of Stotts Island, Tweed River. University of New England. (Unpub.).

A checklist of 79 species, the genera arranged alphabetically in systematically arranged families. Includes common names and abundance information within each community type. Vegetation map.

TWEED HEADS

168 Floyd, A. (1969d). Species list for Whian Whian State Forest. University of New England. (Unpub.).

A checklist of 142 species, the genera arranged alphabetically within systematically arranged families, with common names and abundance information.

TWEED HEADS

169 Floyd, A. (1969e). Whian Whian State Forest, Big Scrub. University of New England. (Unpub.).

A checklist of 111 species, the genera and families arranged systematically. Geological information provided.

TWEED HEADS

170 Floyd, A. (1969f). At the foot of Minyon Falls, Whian Whian State Forest. University of New England. (Unpub.).
A checklist of 46 species, the genera arranged alphabetically within systematically arranged families. Includes abundance estimates.
TWEED HEADS

171 Floyd, A. (1969g). Species list for Acacia Plateau State Forest. University of New England. (Unpub.).
A checklist of 76 species, the genera arranged alphabetically within systematically arranged families. Common names and abundance information provided.
WARWICK

172 Floyd, A. (1969h). Species list for Beaury State Forest. University of New England. (Unpub.).
A checklist of 84 species, the genera arranged alphabetically within systematically arranged families. Common names and abundance information provided.
WARWICK

173 Floyd, A. (1969i). Tooloom State Forest — Scrub. University of New England. (Unpub.).
A checklist of 59 species, the genera and families arranged systematically.
WARWICK

174 Floyd, A. (1969j). Species list for Wiangarie State Forest. University of New England. (Unpub.).
A checklist of 142 species, the genera in alphabetical order within systematically arranged families in the major plant groups.
WARWICK, TWEED HEADS

175 Floyd, A. (1976). Species list — Allambie Island, Taree. (Unpub.).
A checklist of 69 species arranged according to habit in each community type; the genera in alphabetical order within systematically arranged families. Includes common names, abundance information and comments on the condition of the forest. (Note: Allambie Island is now known as Coocumbac Island.)
HASTINGS

176 Floyd, A. (1980). Floral species list of Schnapper Island. In Flora & fauna survey of the proposed Pipe Clay Creek Nature Reserve. (Unpub.). Compiled by G. Bartrim.
Checklist of species arranged within life form and habitat types. The genera are arranged in alphabetical order within systematically arranged families. Common names and abundance information are provided and exotic species marked. See ref. 159 (Bartrim, 1980). Location map.
HASTINGS

177 Floyd, A., & Coveny, R. (1977). Brunswick Heads — species list. Royal Botanic Gardens, Sydney. (Unpub.).
A list of 84 species compiled by Floyd and arranged alpabetically by genus in systematically arranged families with common names and abundance information. An additional 91 species are recorded by Coveny alphabetically by genus.
TWEED HEADS

178 Fox, M. (1983). *A vegetation survey of the Washpool area, northern New South*

Wales. (Department of Environment & Planning: Sydney).

Species listed alphabetically by family and genus in Appendix II. Separate list of rare species with comments in Appendix III. Tree species listed with common names in Appendix IV. The accompanying report describes and classifies vegetation types of the area and evaluates the impact of logging.
GRAFTON

179 Gregson, J. (1902). A list of foliaceous lichens collected from the Gloucester district. (Unpub.).

Ten species listed with authorities determined by E. Cheel, 1902. Vouchers kept at National Herbarium of N.S.W.
NEWCASTLE, HASTINGS

180 Harden, G., Fox, M., & Stockard, J. (1984). Wingham Brush species list. (Unpub.). Based on ref. 175 (Floyd, 1976).

A checklist of 156 species arranged alphabetically by families and genera within the major plant groups. Common names, growth forms and abundance information given and exotic species marked.
HASTINGS

181 National Parks & Wildlife Service (1981). *Mt Warning National Park Draft Plan of Management*. (N.P.W.S.: Sydney).

Five lists for different altitudinal habitats. Families arranged systematically within growth form categories. Common names, abundance estimates and some localities are provided. Exotic species annotated. Subtropical rainforest on low slopes (630m), about 200 spp. Warm tropical rainforest on mid-upper slopes (630–1000m), about 110 spp. Base of rock face (700m), about 70 spp. Rock face (930m), about 35 spp. Top of cliff (1000–1105m), about 25 spp.
TWEED HEADS

182 National Trust of Australia (NSW) (1981). Wingham Brush — Plan of Management. (Unpub.).

About 120 species listed in systematically arranged families within growth form categories. Abundance estimates and common names given.
HASTINGS

183 Outhred, R. K., & Buckney, R. T. (1983). The vegetation of Kooragang Island, New South Wales. *Wetlands* 3: 58–70.

A checklist of 102 species listed alphabetically with quantitative habitat and size class data on some of the dominant trees. Eleven extra species not recorded in sample sites are listed separately. Descriptions of habitat types are included in text.

A more detailed account of the same vegetation survey is given in J. Moss (ed.) (1983), *Investigation of the natural areas of Kooragang Island*. (Department of Environment & Planning: Sydney).
NEWCASTLE

184 Pressey, R. L. (1981). A survey of wetlands on the lower Hunter flood plain. National Parks & Wildlife Service. (Unpub.).

Wetlands are mapped, described and evaluated. The extent of 25 wetland habitats is estimated at 168 sites. Most are characterized by single species; the species composition of the more complex habitats is described in the text. Location map.
NEWCASTLE

185 Rodd, A. N. (1981). List of species collected from rainforest at Mungo Brush.

(Unpub.).

A checklist of 42 species arranged alphabetically by families and genera in the major plant groups. Specimens lodged at the National Herbarium of N.S.W. are annotated with collecting numbers.

NEWCASTLE

186 Waterhouse, D. R. (1976). *Four conservation areas for Newcastle — proposals of the National Parks Association of New South Wales* (National Parks Association of New South Wales: Sydney).

Common species mentioned in text for Sugarloaf Range, Bow Wow Creek and Pipe Clay Creek. Five plant communities are briefly described with a list of c. 70 species for the Newcastle Bight dunes arranged alphabetically by genus.

NEWCASTLE

187 White, E. G., Griffith, S. J., & Quint, G. (1984). List of native plants at Goanna Headland. Classification Card for Goanna Headland Coastal Conservation Area. National Trust of Australia (NSW). (Unpub.).

A checklist of 245 species arranged alphabetically by families and genera within the major plant groups. Common names given.

MACLEAN

188 Williams, J. B. (1982). *Plants of coastal heath, scrub and swamp-heath in northern New South Wales*. (University of New England: Armidale).

A checklist of 360 species arranged alphabetically by families and genera within the major plant groups. Includes information on vegetation type and soil type for each species. Text discusses soil–vegetation relationships. List covers coastal areas north of Macleay River.

COFFS HARBOUR, DORRIGO, MACLEAN, TWEED HEADS

For additional lists also relevant to the North Coast see ref. 189 (Adam, 1981), ref. 194 (Archer, 1980), and ref. 282 (Stevens, 1979).

CENTRAL COAST

189 Adam, P. (1981). Saltmarsh plants of New South Wales. *Wetlands* 1: 11–19.

Includes descriptions, illustrations and a key to 42 common saltmarsh plants of New South Wales.

TWEED HEADS, MACLEAN, COFFS HARBOUR, HASTINGS, NEWCASTLE, SYDNEY, WOLLONGONG, ULLADULLA, BEGA, MALLACOOTA

190 Adam, P., & King, R. J. (1981). *The Botany of Botany Bay.* Field Excursion Handbook No. 44. (XIII International Botanical Congress: Sydney).

A brief description of the mangrove, saltmash, forest and coastal heath communities, with checklists for the saltmarshes and mangroves (9 species) and coastal heaths (163 species); the families and genera arranged alphabetically within the major plant groups.

SYDNEY, WOLLONGONG

191 Adam, P., & Murray, A. (1979). Long Neck Lagoon — species list. (Unpub.).

Checklist of 74 species, the genera arranged alphabetically within systematically arranged families.

SYDNEY

192 Akkersdyk, P. (1984). Royal National Park species list. (Unpub.).

A checklist of about 1080 species arranged alphabetically by families and genera.

WOLLONGONG

193 ANZAAS (1952). Notes on Excursion No. 23. Ku-ring-gai Chase–Church

Point–Long Reef. (Unpub.).

Includes checklists for laterite forest, Sorlie (67 species); sandstone scrub, McCarrs Creek (164 species); brush forest, McCarrs Creek (62 species); mangroves and saltmarsh, Bayview (8 species); and brackish lagoon sedge meadow, Dee Why (47 species); arranged in systematic order. Text describes the route of the excursion and the climate, geology, physiography, soils and vegetation of the area.

SYDNEY

194 Archer, A. W. (1980). List of lichens collected in New South Wales 1977–1980. (Unpub.).

A checklist of lichen species found in eastern N.S.W., the genera arranged alphabetically within each locality. Includes more detailed location and habitat information.

SYDNEY, WOLLONGONG, NEWCASTLE, DORRIGO

195 Benson, D. H. (1978). Vegetation Survey: Mt White–Calga/Kariong. In *Freeway No. 3 — Sydney–Newcastle Freeway. Section — Mount White to Ourimbah. Environmental Impact Statement.* Additional Environmental Information Volume. (New South Wales Department of Main Roads: Sydney).

Description of 11 vegetation communities with information on the main species, habitat, distribution and impacts of proposed freeway. Additional comments are provided on species richness and rare species. Location and vegetation maps. For the corridor between Kariong and Ourimbah see ref. 209 (Benson & Fallding, 1979).

SYDNEY

196 Benson, D. H. (1979). Report on native vegetation — Edna May Hunt Reserve, Hillside Crescent, Epping. (Unpub.).

Includes a brief description of the vegetation communities and a checklist of 65 species, arranged alphabetically by genus, annotated with families, common names, and growth form information. Introduced species marked.

SYDNEY

197 Benson, D. H. (1981a). Flora of the Minnamurra Falls Reserve, New South Wales. Compilation of the lists of L. A. S. Johnson (1953), R. Coveny (1979) and H. Judd. (Unpub.).

Lists arranged in major plant groups, under growth form headings, coded for abundance and habitat; about 270 species.

WOLLONGONG

198 Benson, D. H. (1981b). Vegetation of Upper Mangrove Creek, Wyong, New South Wales. *Cunninghamia* 1: 7–22.

A checklist of 196 species arranged alphabetically by families and genera. Occurrence in each of four communities is recorded. Text describes four vegetation communities.

SYDNEY

199 Benson, D. H. (1981c). Vegetation of the Agnes Banks sand deposit, Richmond, New South Wales. *Cunninghamia* 1: 35–58.

A checklist of 136 species listed alphabetically by families and genera within the major plant groups. Table shows growth form, frequency of occurrence, and mode of regeneration after fire. Text describes five vegetation communities and discusses the results of ordination and cluster analyses.

SYDNEY

200 Benson, D. H. (1981d). Vegetation of Lion Island, Broken Bay, New South Wales. *Cunninghamia* 1: 121–124.

A checklist of 90 species listed alphabetically by families and genera within the major plant groups. Text includes a brief description of the vegetation.
SYDNEY

201 Benson, D. H. (1983). Plant species originally native in Concord Municipality. In S. Coupe (ed.), *Concord: a centenary history* (Concord Municipal Council: Concord).
Checklist of 84 species listed alphabetically by family with common names, growth form and geological information. A brief description of Concord's original vegetation is presented in Chapter 1.
SYDNEY

202 Benson, D. H. (1984a). List of plants growing on Bar Island, Hawkesbury River. (Unpub.).
A checklist of 90 species arranged alphabetically by families and genera.
SYDNEY

203 Benson, D. H. (1984b). Floristic lists for Sydney Region Vegetation Series 1:100 000 map sheets. (Unpub.).
Floristic lists of varying length for native species for Gosford and Lake Macquarie, Wallerawang and Burragorang 1:100 000 map sheets with major plant communities indicated. Lists are progressively updated and expanded.
SYDNEY, WOLLONGONG

204 Benson, D. H. (1985a). List of native plants growing on Goat Island, Sydney Harbour. (Unpub.).
A checklist of 44 species arranged alphabetically by families and genera within the major plant groups.
SYDNEY

205 Benson, D. H. (1985b). Species list for upper Magdala Creek, Springwood. (Unpub.).
A checklist of 60 species arranged alphabetically by families within the major plant groups. Exotics indicated.
SYDNEY

206 Benson, D. H. (1985c). Aspects of the ecology of a rare tree species *Eucalyptus benthamii*, at Bents Basin, Wallacia. *Cunninghamia* 1: 371-383.
A checklist of 86 species associated with *E. benthamii* arranged alphabetically by families and genera in the major plant groups. Exotic species marked as garden escapes or agricultural weeds.
SYDNEY

207 Benson, D. H., Coveny, R., & Hind, P. (1983–84). Floristic list for Castlereagh State Forest. (Unpub.).
Checklist of 258 species arranged alphabetically by families and genera within the major plant groups. Includes six fungi species. Exotic species indicated.
SYDNEY

208 Benson, D.H., Coveny, R., & Keith, D.A. (1985). Native species recorded in Mill Stream section of Botany Swamps. (Unpub.).
A checklist of 51 species arranged alphabetically by families and genera in the major plant groups.
SYDNEY

209 Benson, D. H., & Fallding, H. B. (1979). Vegetation Survey: Kariong–

Ourimbah. In *Freeway No. 3 — Sydney–Newcastle Freeway. Section — Mt White to Ourimbah. Enironmental Impact Statement.* Additional Environmental Information Volume. (New South Wales Department of Main Roads: Sydney).

A checklist of 310 species listed alphabetically by genus within growth form categories. Family names and the occurrence of each species in respective vegetation communities are indicated and exotic species marked. Accompanying text includes impacts of the proposal. Vegetation map. For the corridor between Mt White and Kariong see ref. 195 (Benson, 1978).
SYDNEY

210 Benson, D. H., & Keith, D. A. (1984a). Floristic list for Dalrymple Hay Nature Reserve. (Unpub.).

A checklist of 92 species arranged alphabetically by family and genus within the major plant groups.
SYDNEY

211 Benson, D. H., & Keith, D. A. (1984b). Floristic list for Fagan Park, Galston. (Unpub.).

A list of 85 species arranged alphabetically by families and genera.
SYDNEY

212 Benson, D. H., & Keith, D. A. (1984c). Floristic list for Macquarie Hospital Bushland, Twin Road and Cressy Road, East Ryde. (Unpub.).

A checklist of 123 species arranged alphabetically by families and genera within the major plant groups. Abundance and occurrence on sandstone or shale is indicated for each species.
SYDNEY

213 Benson, D. H., & Keith, D. A. (1985a). Species list for the Leo Smith Reserve, Ramsgate. (Unpub.).

A checklist of 63 species arranged alphabetically by families and genera in the major plant groups with abundance information and exotic species marked.
SYDNEY

214 Benson, D.H., & Keith, D.A. (1985b). List of native species recorded on Metropolitan Water, Sewerage & Drainage Board proposed water pollution control plant site, Rouse Hill. (Unpub.).

A checklist of 99 species arranged alphabetically by families and genera with abundance estimates for the occurrence of each species in sandstone woodland or along a creek.
SYDNEY

215 Benson, D.H., Keith, D.A., & Dalby, J. (1985). Native flora of Silverwater Armament Depot. (Unpub.).

Separate checklists for forest on shale (103 spp.) and wetlands (19 spp.), arranged alphabetically by families and genera within the major plant groups.
SYDNEY

216 Benson, J. S. & Fallding, H.B. (1981). Vegetation survey of Brisbane Water National Park and environs. *Cunninghamia* 1: 79–113.

A checklist of 657 species listed alphabetically by families and genera in the major plant groups with annotations showing the occurrence of each species in relevant vegetation communities. Descriptions of the study area, vegetation communities, rare and restricted species and comments on their conservation status are given in the text. Vegetation map at 1:50 000 scale.
SYDNEY

217 Betteridge, C. (1981). *The Plants of Gore Hill Cemetery.* Heritage Council Newsheet 6. (Department of Environment and Planning: Sydney).

A checklist of 123 species listed alphabetically by genus within growth form categories. A listing of plants and their symbolism is also given. Text contains an appraisal of the landscape and vegetation of the cemetery.

SYDNEY

218 Blombery, A. M. (1973). Stony Range Flora Reserve. *Austral. Pl.* 7: 94–156.

Includes a checklist of 548 species cultivated in the reserve, arranged alphabetically by families and genera. Brief description of each species; those native to the reserve or area are indicated. Text describes vegetation, topography, history and horticultural practices in the reserve.

SYDNEY

219 Buchanan, R. A. (1979). *Mowbray Park: description and management.* (Mowbray Park Preservation Society: Sydney).

Description of vegetation and topography for bushland along Lane Cove River with management recommendations. List of over 200 species under major plant groupings, arranged alphabetically within families. Weeds and endangered species indicated.

SYDNEY

220 Buchanan, R. A. (1980). The Lambert Peninsula, Ku-ring-gai Chase National Park. Physiography and the distribution of podzols, shrublands and swamps, with details of the swamp vegetation and sediments. *Proc. Linn. Soc. N.S.W.* 104: 73–94.

List of 44 species found in four swamp types and in moist shrubland. Text describes vegetation and geomorphology of the study area.

SYDNEY

221 Buchanan, R. A. (1982). Ahimsa — plan of management. (Unpub.).

A checklist of 149 species listed alphabetically by families and genera, with abundance estimates for each species on different sections of the National Trust property at Cheltenham. Weed species and ornamental introductions indicated. Text contains a description of the vegetation and discusses management issues.

SYDNEY

222 Buchanan, R. A., & Humphreys, G. S. (1980). The vegetation on two podzols on the Hornsby Plateau, Sydney. *Proc. Linn. Soc. N.S.W.* 104: 49–71.

Species list in appendix. Sixty-four species arranged alphabetically within systematically arranged families in the major plant groups. Text discusses vegetation patterns on the podzols.

SYDNEY

223 Clark, S. S. (1984). Report on areas of closed (rainforest) vegetation. Proposed waste emplacement area, South Bulli Colliery, Bellambi Coal Company. (Unpub.). Cited as an appendix in the Environment Impact Statement for the above proposal.

A checklist of 74 species arranged alphabetically by genus within systematically arranged families under growth form headings. Presence/absence recorded for four different areas. Text describes vegetation and evaluates its condition.

WOLLONGONG

224 Clemens, J. (1984). Species list for North Head Peninsula. (Unpub.).

A checklist of 232 species, the families and genera arranged alphabetically within the major plant groups. Endangered, protected and

introduced species indicated.
SYDNEY

225 Clemens, J., & Franklin, M. H. (1980). A description of coastal heath at North Head, Sydney Harbour National Park: Impact of recreation and other disturbance since 1951. *Aust. J. Bot.* 28: 463–478.
Two types of heath identified, with species lists of 13 and 26 respectively. Mode of regeneration after fire given for each species.
SYDNEY

226 Collier, B. (1983). Plant list of Munmorah State Recreation Area to 25/4/83 with additions to 9/5/83. (Unpub.).
A checklist of 262 species arranged alphabetically by genus with widespread, common and locally abundant species marked. Tentative identifications are indicated for some taxa.
SYDNEY

227 Coveny, R. G. (1982). Checklist for Maddens Plains—about 1km north of Sublime Point. (Unpub.).
A checklist of 190 species listed alphabetically by genera, exotics indicated, includes some fungi.
WOLLONGONG

228 Coveny, R. G. (1983). Wheeny Creek, Wollemi National Park. (Unpub.).
Checklist of 196 species arranged alphabetically by genus with exotic species marked.
SYDNEY

229 Davenport Campbell & Partners Pty Ltd (1984). Singles Ridge Area Local Environmental Study. (Unpub.).
Checklists for Purvines Road (57 native species), Yellow Rock Trail (26 native species), downstream of North Richmond Sewerage Works (24 native species) and weeds noted on Fraser and Fitzgeralds Creeks (13 species) listed under habitat types and growth form categories. Text contains a brief description of the vegetation and an assessment of weed invasion. Singles Ridge is near Springwood.
SYDNEY

230 Elouera Bushland Natural Park Trust (1983). *A Guide to Elouera Bushland Natural Park*. (Elouera Bushland Natural Park Trust: Hornsby).
A checklist of 430 species is presented in Appendix 2, arranged alphabetically by genera with exotic species indicated.
SYDNEY

231 Farrant, P. A., & King, R. J. (1982). Subtidal seaweed communities of the Sydney region. *Wetlands* 2: 51–60.
A checklist of 59 algal species arranged in divisions, orders, families and genera with locality information for five sites in Sydney Harbour. Text describes algal associations at each site and discusses distributional patterns.
SYDNEY

232 Fuller, L. (1980). *Wollongong's native trees*. (L. Fuller & R. Badans: Kiama).
Over 120 species described alphabetically by genus with photographs and distribution maps. Additional notes on habitats and plant communities. A general overview of the history and geography of Wollongong is also presented.
WOLLONGONG

233 Fuller, L., & Mills, K. (1985). *Native Trees of central Illawarra* (Weston & Co. Publishers Pty Ltd: Kiama).

Drawings, brief descriptions and distribution maps of 140 tree species arranged alphabetically by genus. Common names and families given. Includes photographs of a further 24 shrub species sometimes encountered as trees. Appendix lists trees typically found in 14 different habitats. Text describes landforms, geology and climate of area and discusses patterns of distribution.

WOLLONGONG

234 Haegi, L., & Benson, D. H. (1981). *Sclerophylls, sandstone and scenic splendor: a wilderness walk in Wollemi National Park, N.S.W.* Field Excursion Handbook No. 18/4 and 18/5. (XIII International Botanical Congress: Sydney).

Checklists of main species are given for Culoul Range turnoff (28 species); basalt vegetation — Six Brothers to Hollow Rock (54 species); Boorai Ridge (58 species); Colo Gorge and Dooli Creek (90 species); Dooli Creek Waterfall (17 species); Boorai Creek (76 species); Mopoke Flat Campsite (12 species); sandstone slopes near Mopoke Flate Campsite (10 species); and Mopoke Flat to Hollow Rock (46 species); all arranged alphabetically by genus within growth-form categories. Common names and families given.

SYDNEY

235 Hickey, E., & Quint, G. (1982). Royal Australian Navy Land — Silverwater, Plant Listing. (Unpub.).

A checklist of 46 species listed alphabetically by families and genera within the major plant groups. Common names given and exotic species marked.

SYDNEY

236 Holland, D. (1980). Mount Trefle: A general and botanical study within Sydney Harbour National Park. Student report for Ryde School of Horticulture. (Unpub.).

Text describes the history, geology, soils, climate and vegetation of the area with specific comments on plant communities, fire and weed control. Checklist of 115 species arranged alphabetically by families and genera, exotic species marked. A separate list shows community composition.

SYDNEY

237 Hutchings, P. A., Pickard, J., Recher, H. F., & Weate, P. B. (1977). A survey of mangroves at Brooklyn, Hawkesbury River. *Operculum* 5: 105–112.

A brief account of the flora of the mangrove communities and their associated fauna with an evaluation of the effects of reclamation. Includes qualitative transect data for vegetation and quantitative transect data for fauna.

SYDNEY

238 Jarvie, L., Pople, L., Robertson, C., & Sajn, D. (1985). List of vascular plant species for Davidson State Recreation Area. (Unpub.).

A checklist of 454 species arranged alphabetically by families and genera within the major plant groups. Sources of other records given. Exotic and rare and endangered species marked.

SYDNEY

239 Keith, D. A. (1984). Plant species occurring in a park on the corner of Epping Road and Delhi Road, North Ryde. (Unpub.).

A checklist of 109 species arranged alphabetically by families and genera

within the major plant groups. Each species is categorized as indigenous, cultivated or exotic and abundance estimates are given. Comments are made regarding the value of this area with respect to remnant vegetation on Sydney's Wianamatta Shale and the effect of cultivating non-indigenous Australian native plants in such areas.
SYDNEY

240 Keith, D. A. (1985). Species list for Eric Mobbs Reserve, Carlingford. (Unpub.).
A checklist of 95 species arranged alphabetically by families and genera within the major plant groups. Exotic species marked.
SYDNEY

241 Keith, D.A., & Fallding, H.B. (1985). Prospect Creek, Smithfield, species list. (Unpub.).
A checklist of 76 species arranged alphabetically by families and genera within the major plant groups. Exotic species marked.
SYDNEY

242 Kinhill Stearns (1985). Native plant species occurring on the proposed airport site at Badgerys Creek. In *Draft Environmental Impact Statement for Second Sydney Airport*. (Department of Aviation: Canberra).
A checklist of 71 species in Appendix D arranged alphabetically by genus. Text describes and assesses vegetation. Vegetation map.
WOLLONGONG

243 Kinhill Stearns (1985). Frequency of occurrence of plant species in the vegetation types and in the Allens Creek valley at the proposed airport site at Wilton. In *Draft Environmental Impact Statement for Second Sydney Airport*. (Department of Aviation: Canberra).
A checklist of 350 species in Appendix K arranged alphabetically by genus. Includes frequency data with exotic species marked. Text describes five vegetation communities and assesses their conservation status. Vegetation map.
WOLLONGONG

244 Kohen, J. L., & Edgecombe, A. (1985). Cumberland Plain species list. (Unpub.).
A checklist of 379 species arranged alphabetically by genera. Annotated with collection localities, information on edible parts and other parts used by Aborigines. Exotic species marked.
SYDNEY, WOLLONGONG

245 Linnean Society of New South Wales (1971). Preliminary checklist of plants of Dharug National Park. (Unpub.).
A checklist of 264 species arranged alphabetically by genus with exotic species marked.
SYDNEY

246 McBarron, E. J. (1984). Botanical sampling of cemeteries in Campbelltown, Liverpool, Camden, Narellan and Thirlmere areas. (Unpub.).
A list of 571 species recorded in 18 cemeteries. Arranged alphabetically by genus within growth form types. Non-local and exotic species indicated.
SYDNEY, WOLLONGONG

247 McRae, R. H. D., & Benson, D. H. (1983). Vegetation of Bouddi National Park. (Unpub.).
A checklist of 358 species arranged alphabetically by families and genera

in the major plant groups is given in Appendix 3, annotated with growth form and plant community, with exotic species marked. Extra species recorded by other workers are included in a separate list. Text includes a description of the climate, geology, geomorphology, soils, land uses and six vegetation communities in the study area and discusses several management issues including fire, weed invasion and rare species.
SYDNEY

248 McRae, R. H. D., & Conacher, P. (1980). Vegetation Survey of No. 3 Freeway, Wallarah Creek Interchange to Wallsend. (Unpub.).
Checklists are provided for three sections of the route, with 146, 151 and 150 species respectively, arranged alphabetically by families and genera within the major plant groups. Six vegetation communities are described in the text and the occurrence of species in each is indicated in the lists. Vegetation and location maps. A summarized copy of the report is published in New South Wales Department of Main Roads *Environment Impact Study. Sydney–Newcastle Freeway. Section: Wallarah Creek Interchange to Wallsend.*
SYDNEY

249 Mills, K. (undated). Plant species list for Korrongulla Swamp, Primbee. (Unpub.).
A checklist of 105 species arranged alphabetically by families and genera in the major plant groups. Common names given and exotic species marked. Primbee is near Port Kembla.
WOLLONGONG

250 Mills, K. (1982a). Checklist of the rainforest plants of the Illawarra. Geography Department, Wollongong University. (Unpub.).
Checklist of 178 species arranged in two parts according to growth form (trees and shrubs or creepers, climbers and scramblers), alphabetically by family within the major plant groups. Common names are included.
Also includes checklists for individual sites at Woodhill–Broughton Head, Kangaroo Valley (80 spp.); Upper Brogers Creek, Kangaroo Valley (102 spp.); Upper Burning Palms–Garawarra Range (94 spp.); National Falls, Royal National Park (64 spp.); Bass Point, Shellharbour (77 spp.); Plateau Gully, Barren Grounds Nature Reserve (27 spp.); and Mt Kembla (96 spp.); arranged within growth-form types, alphabetically by genus. Each list accompanied by details of vegetation stucture, geology, aspect, altitude and average rainfall. Extensions of known range indicated.
WOLLONGONG

251 Mills, K. (1982b). Plant species list for the escarpment at Corrimal (end of Glenlea Street). (Unpub.).
A checklist of 105 species arranged alphabetically by families and genera under ferns and flowering plants with common names and exotic species marked. Vegetation profile diagram.
WOLLONGONG

252 Mills, K. (1983a). Plant species list for the Jerrara Dam site, Jamberoo Valley, Kiama, New South Wales. (Unpub.).
A checklist of 165 species listed alphabetically by families and genera under ferns and flowering plants. Common names given and exotic species marked.
WOLLONGONG

253 Mills, K. (1983b). Plant species recorded in the Shellharbour swamp

catchment area. (Unpub.).

A checklist of 67 species arranged alphabetically by genera, each recorded as growing on land-fill, swampland or in remnant forest. Exotic species marked.

WOLLONGONG

254 Mills, K. (1983c). Plant species list for Hicks Creek gully, Asquith Street, Austinmer. (Unpub.).

A checklist of 90 species arranged alphabetically by genera within growth form categories. Exotic species marked. Location map.

WOLLONGONG

255 Mills, K. (1983d). Rainforests of the Illawarra District, New South Wales. Paper presented to Workshop and Open Forum on 'The present and future of Australian Rainforests', Griffith University, Brisbane.

Appendix 1 lists 33 species reaching their northern or southern limit of distribution in the Illawarra District. Text describes the different rainforest communities of the area and discusses their conservation status. Location map.

WOLLONGONG

256 Mills, K. (1984a). Plant species list for the Illawarra rainforests. (Unpub.).

A checklist of 299 species arranged alphabetically by families and genera within the major plant groups. Authorities given and exotic species indicated.

WOLLONGONG

257 Mills, K. (1984b). Preliminary plant list for the Shoalhaven Gorge, incorporating that area adjacent to the Tallowa Dam. (Unpub.).

A checklist of 224 species arranged alphabetically by genera with exotic species marked.

WOLLONGONG

258 Mills, K. (1984c). Vegetation Survey of the Upper Hacking River Catchment. (Unpub.).

Text describes climate, physiography, geology and vegetation communities in the study area, mentioning most abundant species. Conservation status of the area is assessed in relation to Royal National Park. Vegetation map. See ref. 259 (Mills, 1984d).

WOLLONGONG

259 Mills, K. (1984d). Plant lists, Upper Hacking River Catchment Study Area. (Unpub.).

Separate checklists for 40 different sites between Waterfall and Stanwell Tops, each arranged alphabetically by genera with exotic species indicated. Locality map. See ref. 258 (Mills, 1984c).

WOLLONGONG

260 Mills, K. (1985a). Plant species list for vegetation communities in the Otford–Helensburgh area. (Unpub.).

A checklist of 251 species arranged alphabetically by families and genera within the major plant groups. Presence or absence in each of five vegetation communities is recorded and exotic species marked.

WOLLONGONG

261 Mills, K. (1985b). Rainforest plant lists from the Illawarra District, New South Wales. (Unpub.).

A collection of 61 separate checklists arranged in north-south order. Each list includes location, geology, rainfall and altitude of site, date recorded and a brief description of the vegetation. Most lists are arranged alphabetically by genus within growth-form categories. Localities include:
Jibbon Beach, Royal National Park;
Cabbage Tree Basin, Royal National Park;
National Falls, Royal National Park;
Walkers Garden, Royal National Park;
Upper Burning Palms–Garawarra Range, Royal National Park;
Werong Beach, Royal National Park;
Kellys Falls Gully, Stanwell Tops;
Creek east of highway, north of Bellambi Creek;
Mangerton Park, Mangerton;
Mt Kembla Lookout to railway line;
Mt Kembla, west of Wollongong;
Mt Kembla ring track, Illawarra State Recreation Area;
Berkeley Cresent Farm, Berkeley Hills;
Hooka Island, Lake Illawarra;
Gooseberry Island, Lake Illawarra;
Mt Brown, Kanahooka, west of Lake Illawarra;
Mt Warrigal, south of Lake Illawarra;
Wanyambilli Hill;
Wongawilli Colliery;
Upper Avon River Valley;
South Avondale Valley;
Macquarie Pass National Park;
Johnsons Spur, east of Calderwood;
Calderwood (Upper Marshall Mount Creek);
Upper Gallahers Creek, Metropolitan Water Sewerage & Drainage Board Catchment;
Blackbutt Forest Reserve, Shellharbour;
Remnant bush south of Dunsters Lane, Oak Flats;
Whispering Gallery, near Albion Park;
Bass Point, Shell harbour;
Flying Fox Gully, Jamberoo;
Gainsborough Estate, Bombo;
Jerraran Creek Valley;
Bushland remnant south-west of Minnamurra River estuary;
Curramore;
Upper Turpentine Creek, Curramore, Jamberoo Valley;
Portion 20, Knights Hill;
'Fernleigh', Robertson;
Robertson Nature Reserve;
Carrington Falls;
Wild Country Park, Foxground;
Head of Broughton Creek, Foxground;
Plateau Gully, Barren Grounds Nature Reserve;
Headwaters of Brogers Creek;
Upper Brogers Creek;
Highway, 3 km south of Kiama;
Toolijooa Hill, Kiama Municipality;

Baileys Island, Gerroa;
Woodhill–Drawing Room Rocks Track, Barren Grounds;
Woodhill–Broughton Head, Kangaroo Valley;
Devils Glen, Kangaroo Valley;
North end of Blackash Nature Reserve, Cambewarra Range;
Mannings Lookout;
Erith Coal Mine, Bundanoon;
Fairy Bower, Morton National Park;
Sandy Creek, Meryla State Forest;
Tallowa Dam, Shoalhaven Gorge and Bundanoon Creek Gorge;
Creek east of Mt Phillips, Shoalhaven Gorge;
Crooked River and northern end of Seven Mile Beach National Park;
Bens Walk, Nowra;
Bungonia Gorge;
Comerong Island, Shoalhaven River.
WOLLONGONG

262 Mills, K., Muston, R., & Young, A. (1984). Vegetation survey of the Maldon–Dombarton Railway. Part I: Port Kembla to Cordeaux River Bridge site. (Unpub.).

A checklist of 463 species arranged alphabetically by genera in systematically arranged families with annotations relating species to plant communities described in the text. Rare species, exotics and recent name changes are indicated. Location and vegetation maps.
WOLLONGONG

263 Mitchell, J., & Associates (1983). *Lane Cove River State Recreation Area.* (Lane Cove River State Recreation Area Trust: Chatswood).

Includes a checklist of 435 species arranged systematically by families and genera in Appendix 2. Text provides a brief description of the vegetation.
SYDNEY

264 Mount King Ecological Surveys (1984). Flora and fauna survey of the East Hills–Campbelltown Railway. (Unpub.).

One hundred and fifty species listed in alphabetic order by family. Map unit(s) for each species given. Vegetation map.
SYDNEY, WOLLONGONG

265 National Trust of Australia (NSW) (1978). Mosman Municipality — bushland survey. (Unpub.).

About 140 species are listed alphabetically by genus with common names for 14 sites. Weeds, rainforest, wet sclerophyll and dry sclerophyll species are listed separately.
SYDNEY

266 National Trust of Australia (NSW) (1979). Kogarah bushland survey. (Unpub.).

Survey and management recommendations for 16 parks and reserves. About 167 native species are listed alphabetically by family and genus within major plant groups, 52 exotic species are listed separately with common names, occurrence of species in the 16 reserves is indicated.
SYDNEY

267 National Trust of Australia (NSW) (1979). North Sydney bushland survey.

(Unpub.).

Survey for 13 reserves in the municipality. About 113 native species are listed alphabetically under family headings within major plant groups, 52 exotic species are listed separately with common names, occurrence of species in the 13 reserves is indicated.
SYDNEY

268 National Trust of Australia (NSW) (1980a). Narrabeen Lagoon survey. (Unpub.).

Survey with management recommendations for three localities. A checklist of 192 native species arranged alphabetically by families and genera within major plant groups, 35 exotic species listed separately with common names. The occurrence of each species is indicated for three different areas with notes on soils.
SYDNEY

269 National Trust of Australia (NSW) (1980b). Description and management of bushland, West Pennant Hills. (Unpub.).

Survey of area off Castle Hill Road. A checklist of 154 species arranged alphabetically by families and genera within major plant groups, exotics annotated. The occurrence of each species in eight different areas is indicated.
SYDNEY

270 National Trust of Australia (NSW) (1980c). Willoughby Municipality — bushland survey. (Unpub.).

Survey covering bushland reserves in the municipality with reports and management recommendations on thirty-five reserves. A checklist of 212 native species arranged alphabetically by family and genus within major plant groups, 62 exotic species listed separately with common names. The occurrence of each species is indicated for the reserves surveyed.
SYDNEY

271 National Trust of Australia (NSW) (1981a). Woollahra Municipality — bushland survey. (Unpub.).

Survey of five bushland reserves with management recommendations. A checklist of 69 native species arranged alphabetically by family within major plant groups, 52 exotic species listed separately with common names. The occurrence of each species is indicated for five sites.
SYDNEY

272 National Trust of Australia (NSW) (1981b). Hurstville Municipality — bushland survey. (Unpub.).

Discussion and recommendations for 24 sites in the area. About 162 native species listed alphabetically in systematically arranged families under major plant groups, 70 exotic species listed separately with common names. Occurrence of each species is indicated for the 24 reserves surveyed.
SYDNEY

273 National Trust of Australia (NSW) (1981c). Lane Cove River State Recreation Area–Banksia Hill — bushland survey. (Unpub.).

Survey and management recommendations. A checklist of 112 native species listed under systematically arranged families within major plant groups, 29 exotic species listed separately.
SYDNEY

274 National Trust of Australia (NSW) (1981d). Manly Municipality — bushland survey. (Unpub.).

A report on the state of 22 reserves in the municipality. Checklist of 184 native species listed alphabetically under families within major plant groups, 68 exotic species listed separately with common names. Occurrence of each species is indicated for the 22 reserves surveyed.

SYDNEY

275 National Trust of Australia (NSW) (1981c). North Sydney Municipality–Smoothey Park — survey and recommendations. (Unpub.).

Survey and management recommendations. Checklist of 42 native species listed under systematically arranged families within major plant groups, 21 exotic species listed separately.

SYDNEY

276 National Trust of Australia (NSW) (1983). Report on the National Trust survey of the Green Point–Mount Avoca area. (Unpub.).

A checklist of 150 species arranged alphabetically by family and genus within the major plant groups. Common names and the occurrence of each species in respective communities are given. Text describes vegetation communities, compares them with those in Brisbane Water National Park and outlines management problems and recommendations. Location map.

SYDNEY

277 National Trust of Australia (NSW) (1985). List of native plant species — Stanwell Park Coastal Conservation Area. Appendix 1 in Classification Card for Stanwell Park Coastal Conservation Area. (Unpub.).

A checklist of 211 species arranged in systematic order, incorporating tree species recorded by Fuller (1980), ref. 232. Common names given.

WOLLONGONG

278 Outhred, R., Lainson, R., Lamb, R., & Outhred, D. (1985). A floristic survey of Ku-ring-gai Chase National Park. *Cunninghamia* 1: 313–338.

A checklist of 126 indicator species used in the analysis, arranged alphabetically by genera. The text presents a floristic classification scheme for the Park and discusses physiographic and edaphic factors underlying floristic patterns.

SYDNEY

279 Rice, B., & Westoby, M. (1981). Myrmecochory in sclerophyll vegetation of the West Head, New South Wales. *Aust. J. Ecol.* 6: 291–298.

A checklist of 279 species arranged alphabetically by family within the major plant groups for sites used in myrmecochory study. Confirmed and suspected myrmecochores (i.e. plants providing inducements for ants to disperse their seeds) are indicated.

SYDNEY

280 Scarlet, C.A. (1980?). Towra Point lichen species list. (Unpub.).

A checklist of 79 species arranged alphabetically by genus.

WOLLONGONG

281 Selkirk, P., Adamson, D., & Edgecombe, A. (1985). Species list for Greaves Creek Valley, Blackheath. (Unpub.).

A checklist of 242 species arranged alphabetically by genera with exotic species marked.
SYDNEY

282 Stevens, G. N. (1979). Distribution and related ecology of macrolichens on mangroves on the East Australian Coast. *Lichenologist* 11: 293–305.
List of lichen species and their distributions between latitudes 17°S and 38°S on the east coast of Australia. Includes comments on climatic and substrate preferences.
TWEED HEADS, MACLEAN, COFFS HARBOUR, HASTINGS, NEWCASTLE, SYDNEY, WOLLONGONG, ULLADULLA, BEGA, MALLACOOTA

283 South Turramurra Environment Protection (1980). R. A. Buchanan (ed.), *A Plan of Management for South Turramurra Bushland.* (South Turramurra Environment Protection: Sydney).
Separate checklist of 301 native and 49 exotic species arranged systematically by families and genera in the major plant groups. Text describes the history, climate, geology, landscape, fauna and vegetation and discusses management issues.
SYDNEY

284 Sydney Prehistory Group (1983). *In search of the Cobrakal.* Part 1. (National Parks & Wildlife Service: Sydney).
Part 1 includes a vegetation study with a checklist of 328 species for the Georges River area arranged alphabetically by genus, annotated with locality and habitat information. Text describes the vegetation of the area. Vegetation and location maps.
WOLLONGONG

285 Thomas, J., & Benson, D.H. (1985a). Vegetation survey of Ku-ring-gai Chase National Park. (Unpub.).
Includes a checklist of 566 species listed alphabetically by families and genera within the major plant groups. Presence or absence of each species is recorded for 21 plant communities and exotic species are marked. Separate list gives life-form, habit, abundance and source of introduced species. Text describes plant communities, climate, geology, geomorphology, soils, history and land use of the study area and discusses significant vegetation, rare species and management implications. Vegetation map.
SYDNEY

286 Thomas, J., & Benson, D. H. (1985b). Vegetation survey of Muogamarra Nature Reserve. (Unpub.).
A checklist of 393 species arranged alphabetically by families and genera within the major plant groups. Presence or absence is indicated for each plant community and exotic species are marked. Separate list gives common names, locations and life-forms of exotic species. Text describes plant communities, climate, geology, geomorphology, soils, history and land use of the area and discusses significant vegetation, rare species and weed invasion. Vegetation map.
SYDNEY

287 Thomas, J., Burkitt, J., & Benson, D. H. (1984). Vegetation Survey of Bents Basin State Recreation Area. (Unpub.).
A checklist of 358 species arranged alphabetically by families and genera within the major plant groups is given in Appendix 2. Membership of

respective vegetation communities is indicated and exotic species marked. Text includes a description of the geology, physiography and twenty-five vegetation communities and discusses management issues including rare species, fire and weeds. Vegetation map.
SYDNEY

288 Vinicombe, P. (1980). *Prediction and predilection* (National Parks & Wildlife Service: Sydney).
Includes a checklist of 113 species, considered to have been resources for aboriginal populations of the Gosford-Wyong area. List is arranged alphabetically by genera and annotated with information on locality, preparation technique, environment and season of availability.
SYDNEY

289 Webb, J. B. (1981). Vegetation of Spectacle Island, Hawkesbury River, New South Wales. *Cunninghamia* 1: 115–120.
A checklist of 128 species arranged alphabetically by families and genera within the major plant groups. List is annotated with information on rarity and locality, exotic species marked. Text contains brief description of nine vegetation types. Vegetation sketch map.
SYDNEY

290 Wilson, N. C. (1984). The plant communities of the saltmarshes of the Sydney region. B.Sc. (Hons) Thesis, School of Botany, University of N.S.W.
Includes a checklist of 148 species arranged alphabetically by families and genera under flowering plants, algae and mosses with notes on occurrence, environment, distribution and records of previous authors. Exotic species marked.
SYDNEY, WOLLONGONG

291 van der Velde, J. T., & King, R. J. (1984). The subtidal seaweed communities of Bare Island, Botany Bay. *Wetlands* 4: 7–22.
A checklist of 42 species is presented in Figure 5. Text discusses patterns in algal communities at this site.
SYDNEY

For additional lists also relevant to the Central Coast, see ref. 307 (Bowden, 1962); ref. 310 (Fallding & Benson, 1985); ref. 316 (Keith & Benson, 1985); and ref. 319 (Vermeulen, 1985).

SOUTH COAST

292 Boyd, C. O. (1970). Montague Island flora list, extracted from Rodway's diary. (Unpub.).
A checklist of 36 species.
BEGA

293 May, V. (1981). Long term variation in algal intertidal floras. *Aust. J. Ecol.* 6: 329–343.
Checklists for Plantation Point, Jervis Bay (100 species), and Ulladulla Headland, Ulladulla (68 species) arranged alphabetically by genus. Text discusses variations in the abundance of algal species and the factors that may influence this.
ULLADULLA

294 May, V. (1985). Observations on algal floras close to two sewerage outlets.

Cunninghamia 1: 385–394.

Checklists of 37 and 35 species respectively for Ulladulla and Plantation Point arranged alphabetically by genus with data on changes in abundance and periods of occurrence during 1976–1979. Frequency data are presented for species found nearest the sewerage outlets at both sites. Text discusses the effect of sewerage outfall on algal populations.

ULLADULLA

295 Mills, K. (1982). Species list for Meryla–Yarrunga Creek–Wombat Hill. (Unpub.).

A checklist of 168 species arranged alphabetically by genus. Annotations for species observed flowering and fruiting. Exotic species marked.

WOLLONGONG

296 Mills, K. (1985). Vegetation survey of the proposed Shoalhaven–Moruya 132 kv No. 2 transmission line. Electricity Commission of New South Wales. (Unpub.).

Includes four checklists for different sections of the route with 361, 378, 218 and 227 species respectively. Species are arranged alphabetically by families and genera within the major plant groups and are annotated with habitat data. Text describes study area and its plant communities, discusses vegetation patterns, the significance of species and communities, and details recommendations.

WOLLONGONG, ULLADULLA

297 National Parks & Wildlife Service (Nowra–Goulburn District) (1984). Morton Park plants. (Unpub.).

A compilation of lists and information from Miss Cosh, Mr R. Oliver, Mrs R. Roxburgh and ref. 325 (Olsen, 1982). Combined list containing 742 species arranged alphabetically by families and genera within the major plant groups with common names and habit information.

WOLLONGONG, ULLADULLA

298 Outhred, R. (1984). Vascular plants of the Wadbilliga National Park — Provisional species list. New South Wales Institute of Technology. (Unpub.).

A list of 465 species arranged alphabetically by genus within families. Includes notes on rarity for some species. Introduced species marked.

BEGA

For additional lists also relevant to the South Coast see ref. 189 (Adam, 1981); ref. 257 (Mills, 1984b); ref. 282 (Stevens, 1979).

NORTHERN TABLELANDS

299 Fisher, H. J. (1985). The structure and floristic composition of the rainforest of the Liverpool Range, New South Wales, and its relationships with other Australian rainforests. *Aust. J. Ecol.*10: 315–325.

A checklist of 115 species arranged systematically by families and genera with life-form is given in the appendix. Text describes the vegetation and discusses species composition and distribution in relation to other rainforest stands.

TAMWORTH

300 National Parks & Wildlife Service (undated). *Mount Kaputar National Park*

Plan of Management (N.P.W.S.: Sydney).

Vegetation section contains descriptions of eight vegetation types, mentioning typical species.

MANILLA

301 Patrick, W. (1979). Mount Kaputar National Park — a checklist of plants. (Unpub.).

A checklist of 538 species arranged alphabetically by families and genera within the major plant groups. Compiled and updated from lists by Gwen Harden. Common names and habitat notes given for some species.

MANILLA

302 Turner, J. C. (1976). An altitudinal transect in rainforest in the Barrington Tops area, New South Wales. *Aust. J. Ecol.* 1: 155–174.

Includes a checklist of 58 species occurring on the transect. List is arranged systematically and includes information on growth form, frequency and vegetation group. Text discusses altitudinal distribution patterns.

SINGLETON

For additional lists also relevant to the Northern Tablelands see ref. 194 (Archer, 1980); ref. 340 (Williams, 1979).

CENTRAL TABLELANDS

303 Anon. (1981). *Bryophytes of South-eastern Australia.* Field Excursion Handbook No.34. (XIII International Botanical Congress: Sydney).

Contains lists of bryophytes found at Mount Wilson Waterfall Reserve (51 species) and Zig Zag Bend, Mt Wilson (22 species) in the Blue Mountains, arranged alphabetically by genus within the major groups. Text describes the area and lists the main tree species.

SYDNEY

304 Armstrong, J. (1981). *A Botanical excursion to the Blue Mountains.* Field Excursion Handbook No. 19. (XIII International Botanical Congress: Sydney).

A checklist of 163 genera mentioned in the text arranged alphabetically with family names in brackets. Text describes the history, geology, geomorphology and vegetation for a number of sites. Brief lists of main species are given for Narrow Neck, Wentworth Falls, Evans Lookout, Beauchamp Falls, Greaves Creek, Neates Glen, Point Pilcher Swamp, Mount Banks, Mount Wilson, Jenolan Caves, Boyd Plateau and Kanangra Walls. Location map.

SYDNEY

305 Benson, D. H. (1980). Vegetation of Jamison Creek, Wentworth Falls. (Unpub.).

An incomplete list of 35 native and eight exotic species accompanied by a brief description and assessment of the vegetation.

SYDNEY

306 Black, D. (1976). An exploratory survey of the vegetation of the Boyd Plateau. M.Sc. Thesis, Sydney University.

A checklist of 174 species arranged by families in systematic order. Text contains description of plant communities and their associated geology and

topography. Photographs and vegetation map. A summary has been published in 1982 in *Vegetatio* 50: 93–111.
BATHURST, SYDNEY, GOULBURN, WOLLONGONG

307 Bowden, I. (1962). Orchids of the Blue Mountains, N.S.W. *Australian Naturalist* 12: 11–20.
A checklist of 155 orchid species occurring on the mostly sandstone area of the Grose River Catchment and south to the Coxs River accompanied by locality notes for each species, sketches, and comments on interesting records for the area.
SYDNEY

308 Coveney, P. J. (1970). Investigation report for Copperhannia Nature Reserve. (Unpub.).
Includes a checklist of 26 main species and a brief description of the vegetation.
BATHURST

309 Coveny, R. G. (1977). Winburndale Nature Reserve. A plant checklist (Gulf Stream to Winburndale Reservoir). (Unpub.).
A checklist of 156 species arranged alphabetically by genus. Exotic species marked.
BATHURST

310 Fallding, H. B., & Benson, J. S. (1985). Natural vegetation and settlement at Macquarie Pass, Illawarra Region, New South Wales. *Cunninghamia* 1: 285–311.
A checklist of c. 400 species arranged alphabetically by families and genera in the major plant groups, annotated with vegetation community membership, exotic species marked. Text describes 10 vegetation communities, climate, topography, ecology, soils and history of settlement in the area. Vegetation map.
WOLLONGONG

311 Gregson, J. (1902–3). Lichens collected at Mount Wilson. (Unpub.).
46 species listed with authorities, determined by E. Cheel.
SYDNEY

312 Hind, P. (1984). A preliminary checklist of rainforest flora below the dam on Mount Tomah. (Unpub.).
Checklist of 60 species for Mount Tomah Botanic Garden, an annexe of the Royal Botanic Gardens, Sydney. Exotic species indicated.
SYDNEY

313 Keith, D. A. (1984a). Floristic list for swamp near Kedumba Gate, Kings Tableland. (Unpub.).
A list of 19 species arranged alphabetically by families and genera.
SYDNEY

314 Keith, D. A. (1984b). Floristic list for Murphys Glen. (Unpub.).
A list of 33 species arranged alphabetically by families and genera.
SYDNEY

315 Keith, D. A. (1984c). Floristic list for heath adjacent to the Deer Park, Kings

Tableland. (Unpub.).
A list of 48 species arranged alphabetically by families and genera.
SYDNEY

316 Keith, D.A., & Benson, D.H. (1985). Species list for the Katoomba 1:100 000 vegetation map sheet. (Unpub.).
A list of about 650 species arranged alphabetically by families and genera, annotated with plant communities. List is updated as further data is collected.
SYDNEY

317 Lee, R. (1980?). Flora list — Winburndale Nature Reserve. (Unpub.).
A checklist of 313 species arranged alphabetically by families in the major plant groups. A compilation of lists for the area including common names, location and source of identification, for each species. Exotic species marked.
BATHURST

318 National Parks & Wildlife Service (undated). Species list for Evans Crown Nature Reserve. (Unpub.).
An incomplete checklist of 47 species arranged alphabetically by families and genera with some common names given.
BATHURST

319 Vermeulen, R. (1985). Rainforest of the Blue Mountains and Hawkesbury. Part 2 — Floristic list of rainforests in the Wollemi and Blue Mountains. *Hawkesbury Flora* 7: 20–31.
A checklist of 143 species arranged alphabetically by families and genera in the major plant groups. Includes trees and shrubs only. Compiled from a list by Alex Floyd with additional annotations on growth form, height, flowering time, flowers and fruit and rainforest structural formations.
SYDNEY

For additional lists also relevant to the Central Tablelands, see ref. 194 (Archer, 1980); ref. 203 (Benson, 1984b); ref. 295 (Mills, 1982); ref. 297 (National Parks & Wildlife Service, 1984).

SOUTHERN TABLELANDS

320 Benson, J. S. (1982). Plant species identified during a walk in the Mount Tinderry Area — western side of Tinderry Range. (Unpub.).
A checklist of 99 species, the families and genera arranged alphabetically within the major plant groups, with life-form and abundance information. Exotic species marked.
CANBERRA

321 Elix, J. A. (1981). *Sub-alpine and temperate rainforest lichens.* Field Excursion Handbook No. 30. (XIII International Botanical Congress: Sydney).
Contains a checklist of lichens for Mount Aggie, A.C.T. (40 species), and the Monga area (34 species) arranged alphabetically by genus. Text includes site notes.
CANBERRA

322 Helman, C. E., & Gilmour, P. M. (1985). Treeless Vegetation above 1000 metres altitude in the A.C.T. (Unpub.).

Includes a checklist of 408 species arranged alphabetically by families and genera within the major plant groups. Annotated with plant communities. Text describes climate, geology, topography, soils and vegetation of site, and discusses vegetation patterns and management implications.
CANBERRA

323 Ingwersen, F. (1985). *Tidbinbilla Nature Reserve vegetation.* (A.C.T. Parks and Conservation Service, Canberra).
No list. Text describes 15 plant communities with major species, altitudinal range and comments on distribution. Vegetation map.
CANBERRA

324 Mills, K. (1984). Plant species recorded in the Majors Creek study area. (Unpub.).
A checklist of 46 species arranged alphabetically by families and genera with common names and exotic species marked.
CANBERRA

325 Olsen, I. (1982). Plant species list for the Budawang Ranges. Pp. 216–240 in The Budawang Committee (eds), *Pidgeon House and beyond, a guide to the Budawang Range and environs.* (The Budawang Committee: Eastwood).
A checklist of 429 species arranged alphabetically by families within the major plant groups. Notes are provided on the physiography, climate and soils of the study area. The list is annotated with typical heights, flowering time, associations, habitat, distribution and abundance of each species. See ref. 328 (Pickard, 1982).
ULLADULLA

326 O'Neill, M. (1984). Some flora of Bungonia State Recreation Area. (Unpub.).
A checklist of 230 species which have been photographed in Bungonia State Recreation Area, arranged in alphabetical order.
GOULBURN, WOLLONGONG

327 Parris, M., & Wimbush, D. J. (1974). Alpine plants — the alpine plants of the Kosciusko National Park. *Australian Plants* 7: 351–370.
No list, text describes nine plant communities and their habitats, mentioning main species.
TALLANGATTA, BEGA

328 Pickard, J. (1982). Vegetation of the Budawang Range. Pp. 241–249 in The Budawang Committee (eds), *Pidgeon House and beyond, a guide to the Budawang Range and environs.* (The Budawang Committee: Eastwood).
Brief descriptions of 16 vegetation communities are given including dominant species. Vegetation map. See ref. 325 (Olsen, 1982).
ULLADULLA

329 Ramsay, H. P., & Streimann, H. (1984). Mosses and their distribution in the Australian Capital Territory. *Telopea* 2: 559–574.
Checklist of 180 species, the genera arranged alphabetically within systematically arranged families. Local, state and national distributions given. Text provides habitat descriptions. Location map.
CANBERRA

330 Telford, I. R. (1981). *Wilderness walk, Morton National Park.* Field Excursion Handbook No. 18/2. (XIII International Botanical Congress: Sydney).

Contains a checklist of 594 species collected from the northern Budawang Range and held at the National Botanic Gardens, Canberra. List is arranged alphabetically by families and genera within the major plant groups and contains habitat information for each species. Text describes the climate, geology and landforms, soils and vegetation. Location and geological maps.

ULLADULLA

331 Thompson, J. (1981). A key to the plants of the subalpine and alpine zones of the Kosciusko region. *Telopea* 2: 219–297.

A key to vascular plants of this region with brief habitat and distribution notes. Also contains an account of recent history of the area and comments on the origin and distribution of the flora.

TALLANGATTA, BEGA

332 Thompson, J., & Gray, M. (1981). A checklist of subalpine and alpine plant species found in the Kosciusko region of New South Wales. *Telopea* 2: 299–346.

A checklist of 455 species, the genera arranged alphabetically within systematically arranged families. Representative localities and altitudes listed for each species.

TALLANGATTA, BEGA

333 Ward, J. E., & Ingwersen, F. (1979). *A checklist of vascular plant species in the Tidbinbilla Nature Reserve.* Conservation Memoranda No. 8 (Department of the Capital Territory: Canberra).

A checklist of 352 species arranged in alphabetical order by family and genus. Common names given and exotic species marked.

CANBERRA

334 Ward, J. E., & Ingwersen, F. (1984). *Checklist of vascular plant species in the Tidbinbilla Nature Reserve.* Conservation Series No. 8 (Australian Capital Territory Parks & Conservation Service: Canberra).

A checklist of 475 species arranged alphabetically by families and genera within the major plant groups. Annotations are made for exotic species, non-indigenous native species, noxious exotic species, protected species, endangered species and unsubstantiated records of Burbidge & Gray (1970), *Flora of the Australian Capital Territory.* Common names given.

CANBERRA

335 Willis, J. H., & Roger, K. C. (1975). Vascular flora of White Rock Mountains (source of Genoa River near Rockton, New South Wales) and North-West Slopes to Nalbaugh Pine Plantation. (Unpub.).

A checklist of 218 species, arranged alphabetically in families and genera within the major plant groups.

MALLACOOTA

336 Willis, J. H. (1981). Plants of Tinderry Mountains, South-East New South Wales (east of Michelago). (Unpub.).

A combined list from 2 localities (crest of South Tinderry Peak south-eastwards to flats along Roberts Creek, and summit of main Tinderry Peak and its western escarpments to edge of forest on Tea Tree Creek).

Contains 191 species in systematically arranged families within the major plant groups. Exotic species marked.
CANBERRA

337 Wimbush, D. J., & Costin, A. B. (1973). *Vegetation mapping in relation to ecological interpretation and management in the Kosciusko alpine area.* CSIRO Division of Plant Industries, Technical Paper No. 32. (CSIRO: Melbourne).
A description of 12 plant communities with a list of the dominant species. Vegetation map.
TALLANGATTA, BEGA

For additional lists also relevant to the Southern Tablelands, see ref. 297 (National Parks & Wildlife Service, 1984).

NORTH WESTERN SLOPES

338 Fox, B. J., & Briscoe, D. A. (1980). *Pseudomys pilligaensis*, a new species of murid rodent from the Pilliga Scrub, Northern N.S.W. *Aust. Mammal.* 3: 109–126.
Checklist of 113 species at seven mammal capture sites is presented in Appendix 2, arranged in alphabetical order.
NARRABRI

339 Mitchell, P. B., Rundle, A. S., & students (1982). Land Systems of the Pilliga Region N.S.W. Macquarie University. (Unpub.).
Species list from all available literature, not field checked. Common names and some habitats given. Map.
NARRABRI

340 Williams, A.R. (1979). *A survey of natural pastures in the North-West Slopes of New South Wales.* Technical Bulletin 22. (Department of Agriculture: Sydney).
A checklist of 550 species, the families and genera listed alphabetically, with abundance and soil type information. Text contains descriptions of vegetation communities and discussion of their relationships with soil type, climate, topography and land use.
INVERELL, MANILLA, TAMWORTH

CENTRAL WESTERN SLOPES

341 Croft, K., & Associates (1984). Botany, wildlife and ecological studies. In *Hunter Valley No. 2 Mine Environmental Impact Statement.* Vol. 2. Supporting Studies. (Coal & Allied Operations Proprietary Limited: Newcastle).
A checklist of about 130 species at the study site, arranged alphabetically by family and genus. Common names, growth form and local abundance given for each species. Text describes six vegetation communities and discusses their conservation status.
SINGLETON

342 Dorman, H. C. (1972). Lees Pinch–Murrumbo flora and bird list. *Hunter Natural History* 4: 269.
A checklist of 338 species arranged in systematic order. Rare and unusual species annotated. Details of locality and collector given.
SINGLETON

343 Fallding, H. B. (1985). The native plants of the Wyalong district and the contribution of Anne Mitchell (1904–1981). (Unpub.).

A checklist of 337 species collected by Anne Mitchell, arranged alphabetically by families and genera. Collection notes include common name, locality, date and habitat. Text describes the area, its climate, geology and seven vegetation types with comments on three rare species.

FORBES

344 Ingram, C. K. (undated). Flora of Lees Pinch, Upper Goulburn River, N.S.W. (Unpub.).

A checklist of 273 species arranged in systematic order with common names. Records for Lees Pinch and Bylong Valley noted.

SINGLETON

345 McRae, R. H. D., & Cooper, M. G. (1985). Vegetation of the Merriwa area, New South Wales. *Cunninghamia* 1: 351–369.

A checklist of 306 species arranged alphabetically in families and genera in the major plant groups, annotated with vegetation community and growth form with exotic species marked. Text describes six vegetation communities, climate, geology, geomorphology, soils and land use and comments on vegetation patterns, rare species and communities. Vegetation map.

SINGLETON

346 National Parks & Wildlife Service (undated). Species list for Conimbla National Park. (Unpub.).

Data sheets listing 163 species with information on habitat, abundance and flowering and seeding times.

BATHURST

347 National Parks & Wildlife Service (undated). Species list for Currumbenya Nature Reserve. (Unpub.).

Data sheets listing 152 species with information on habitat, abundance, flowering and seeding times.

FORBES, BATHURST

348 National Parks & Wildlife Service (undated). Species list for Weddin Mountains National Park. (Unpub.).

Data sheets listing 274 species arranged alphabetically by families and genera with information on habitat, abundance and flowering times. Some common names given.

FORBES

349 Soil Conservation Service of New South Wales (1982). *Wellington Technical Manual* (Soil Con.: Sydney).

Descriptions of eleven plant communities mentioning only the main species. Vegetation map.

DUBBO

350 Thompson, L., Brickhill, J., Fallding, H., & Johnston, J. (1978–1979). Flora of Ingalba Nature Reserve. (Unpub.).

A checklist of 84 species arranged alphabetically by family and genus within the major plant groups. Common names given and exotic species marked.

COOTAMUNDRA

SOUTH WESTERN SLOPES

351 Keith, D. A., & Pellow, B. J. (1985). Preliminary species list for Burrinjuck Dam area. (Unpub.).

A checklist of about 100 species arranged alphabetically by families and genera within the major plant groups. Locality information given for eight sites, exotic species marked.

GOULBURN

352 Mulham, W. E., & Jones, D. E. (1981). Vascular plants of the Riverine Plain of New South Wales — Supplementary List. *Telopea* 2: 197–213.

A list of 200 plant collections, the genera arranged alphabetically within systematically arranged families. Collection notes include common names, detailed locality, distribution, abundance and value to stock. Exotic species indicated. Supplements the list of Leigh & Mulham (1977) *Telopea* 1: 225–293.

BALRANALD, BOOLIGAL, IVANHOE, DENILIQUIN, HAY, WANGARATTA, JERILDERIE, NARRANDERA, CARGELLIGO, NYMAGEE

NORTH WESTERN PLAINS

353 Cunningham, G. M., & Milthorpe, P. L. (1981). The vascular plants of five exclosure sites in western New South Wales. *Cunninghamia* 1: 23–34.

A checklist of 401 species arranged alphabetically by family and genus. Site shown for each. Presence of each species at each site is recorded and exotic species marked. Text describes the sites and comments on the effect of fencing on vegetation communities.

MANARA, BOOLIGAL, IVANHOE, CARGELLIGO, NYMAGEE, COBAR, FORBES

354 Cunningham, G. M., Mulham, W. E., Milthorpe, P. L., & Leigh, J. H. (1981). *Plants of Western New South Wales* (Soil Conservation Service of New South Wales & Government Printing Office: Sydney).

Descriptions of about 2000 species arranged alphabetically by genus within systematically arranged families. Notes on habitat, distribution, growth characteristics and responses to seasonality and grazing. Photographs and common names provided.

355 Moore, C. W. E. (1984). *Annotated checklist of the vascular plants in part of north-western New South Wales.* CSIRO Division of Land Resources Management Technical Memorandum 84/30. (CSIRO: Canberra).

A checklist of 784 species arranged alphabetically by genus in systematically arranged families. Notes for each species include collecting numbers for specimens held at Herbarium Australiense, localities and habitat information. Text contains descriptions of climate, topography and plant communities.

NYNGAN, BOURKE, BARNATO, WILCANNIA, COBAR, LOUTH, YANTABULLA

356 Thompson, J. (1968–1970s). A list of plants collected in the Brewarrina area. (Unpub.).

A checklist of 226 species arranged systematically in families and genera with collection notes and numbers.

ENNGONIA, BOURKE

For additional lists also relevant to the North Western Plains, see ref. 338 (Fox &

Briscoe, 1980); ref. 339 (Mitchell *et al.*, 1982); and ref. 340 (Williams, 1979).

SOUTH WESTERN PLAINS

For lists relevant to the South Western Plains, see ref. 354 (Cunningham *et al.*, 1981).

NORTH FAR WESTERN PLAINS

357 Anon. (1970–71). Checklist of flora identified at Mootwingee Historic Site. (Unpub.).

Checklist of 174 species, the families and genera arranged in systematic order, with reference numbers and brief notes on habit, habitat and common names.

BROKEN HILL

358 Emerick, J. O. (1985). *Environmental Impact Statement for a high temperature incinerator at The Gorge* (Rinex Environmental Services Pty Ltd: Sydney).

A checklist of 77 species is given in Appendix 6, arranged alphabetically by genera with authorities, families and common names. Text describes and assesses vegetation of The Gorge, near Broken Hill.

BROKEN HILL

359 Mahood, I. T. (undated). Plant list for Gnalta National Park and Coturaundee Nature Reserve. Compiled from an Investigation Report by National Parks & Wildlife Service, Soil Conservation Report, and collections of I. Mahood. (Unpub.).

Checklist of 106 species with common names, the genera arranged alphabetically in systematically arranged families with references to Black's *Flora of South Australia*. Accompanied by a detailed description of three major plant communities.

BROKEN HILL, WILCANNIA, COBHAM LAKE, WHITE CLIFFS

360 Pickard, J. (1978). Vegetation map of North Western New South Wales. Royal Botanic Gardens, Sydney. (Unpub.).

68 vegetation associations with structural forms. Dyeline map 1:1 000 000 and brief accompanying notes.

MILPARINKA, URISINO, YANTABULLA, COBHAM LAKE, WHITE CLIFFS, LOUTH, BROKEN HILL, WILCANNIA, BARNATO

For additional lists also relevant to the North Far Western Plains, see ref. 353 (Cunningham & Milthorpe, 1981); ref. 354 (Cunningham *et al.*, 1981); and ref. 363 (Lubeke *et al.*, 1980).

SOUTH FAR WESTERN PLAINS

361 George, I. (1972). Wattles of the Mildura area. *Sunraysia Naturalists Research Trust, Ninth Report*: 24–27.

18 *Acacia* species found near Mildura divided into five taxonomic groups, distribution, localities, habitat, common names.

MILDURA

362 Henshall, T. S. (1972). A checklist of the flora of the Kings Billabong Area. *Sunraysia Naturalists Research Trust, Ninth Report*: 31–37.

A list of 250 species arranged alphabetically by genus in systematically arranged families. Common names given and exotic species marked.

MILDURA

363 Lubeke, E., Lubeke, J., Petersen, I., Reeves, P., Wall, J., & Wall, B. (1980). Broken Hill : Field Naturalists Club of Victoria 25/8/79 to 6/9/79. *The Victorian Naturalist* 97: 222–224.

Contains a list of about 70 species noted flowering between Mildura and Broken Hill. Includes common names and brief locality notes.

MILDURA, ANABRANCH, MENINDEE, BROKEN HILL

For additional lists also relevant to the South Far Western Plains, see ref. 354 (Cunningham *et al.*, 1981).

NEW SOUTH WALES — GENERAL

364 Drake, W. E., & Specht, R. L. (1980). Reference list — heath/sclerophyll vegetation species lists. Prepared for the Australian Heritage Commission. (Unpub.).

A record of comprehensive floristic lists: 14 from Queensland, 11 from New South Wales, 11 from Victoria, 11 from Tasmania, 10 from South Australia, 2 from Northern Territory and 8 from Western Australia and a list of poorly recorded localities.

365 Ramsay, H. P. (1984). Census of New South Wales mosses. *Telopea* 2: 455–534.

Checklist of 527 species, arranged alphabetically by genus in systematically arranged families with distribution information. Also contains list of references.

366 Ramsay, H. P. (1984). Phytogeography of the mosses of New South Wales. *Telopea* 2: 535–547.

List of species apparently endemic to New South Wales, arranged alphabetically by genus in systematically arranged families with distribution information. Rare species indicated. Text discusses relationships, distribution patterns and endemism.

367 Sammy, N. (1980a). Records of New South Wales lichens housed in the Cryptogamic Herbarium, British Museum (Natural History), London. (Unpub.).

A checklist of 20 species with collectors' names, localities, dates and annotations, and corrected taxa with determinavits where appropriate. Type specimens marked. Mostly eastern New South Wales. Includes a list of lichen collectors and references.

368 Sammy, N. (1980b). Records of New South Wales lichens housed in the Herbarium of the Conservatoire at Jardin Botaniques, Geneva. (Unpub.).

A checklist of 69 species with collectors' names, localities, dates and annotations, and corrected taxa with determinavits where appropriate. Type specimens marked. Mostly eastern New South Wales. Includes a list of lichen collectors and references.

369 Sammy, N. (1980c). Collections of New South Wales lichens housed at the Adelaide Herbarium. (Unpub.).

A list of eight collections of the species *Parmelia amphixantha* with collectors' names, date and location.

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The effect of drought and position in the dam on the algal composition of two dams in New South Wales

V. May

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Abstract

May, V. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1988. The effect of drought and position in the dam on the algal composition of two dams in New South Wales. Cunninghamia 2(1): 75–84. — The effect of drought and position in the dam on algal composition was investigated at two dams in New South Wales.

Introduction

Phytoplankton studies were carried out on two dams in the Hunter River Valley, New South Wales, to study the effects of drought and position in the dam on the algal composition. Water samples were made at 2–4 week intervals from five stations in Lostock Dam (32°10′S; 151°05′E) (Figure 1) between May 1979 and April 1983, and from five stations in Glenbawn Dam (32°04′S; 150°55′E) (Figure 2) between September 1978 and January 1982. The period of drought was 1980–1981, and the effects were more severe at Glenbawn. Methods are as for May & Powell (1986). Full data sets are held by the Library, National Herbarium of New South Wales, Royal Botanic Gardens, Sydney.

Results and Discusssion

Number and distribution of taxa[1]

Of the 68 algal taxa recorded from Lostock Dam, 36 were common, 27 rare and five were found only as drift material (Table 1, Frequency).

In Glenbawn Dam, 34 taxa were recorded as common, 20 as rare and four as drift material (a total of 58 algal taxa) (Table 1, Frequency).

Thirty of the common taxa were found in both dams though abundance data for these taxa varied greatly (Table 1, Abundance)[2]. It was particularly noticeable that the potentially toxic algae *Anacystis* and *Anabaina* were not prevalent in Lostock, though often abundant in Glenbawn. These differences in abundance are explained probably by the high rate of flow and low retention time shown by the water in Lostock, compared with Glenbawn and other dams (Chaffey, May & Powell, 1986, and Carcoar, May, 1988) which all show the same high abundance ratings of toxic algae, low rate of flow and high retention time.

Seasonal growth

Seasonal appearance of taxa in Lostock was variable from year to year. In Glenbawn, some taxa recurred annually, while others showed a seasonal

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[1] Where only one species of a genus is reported, the generic name alone is used. A full list of species names and authorities is given in Table 1.

[2] This high number of taxa common in both dams is not surprising considering the wide distribution of many freshwater algae.

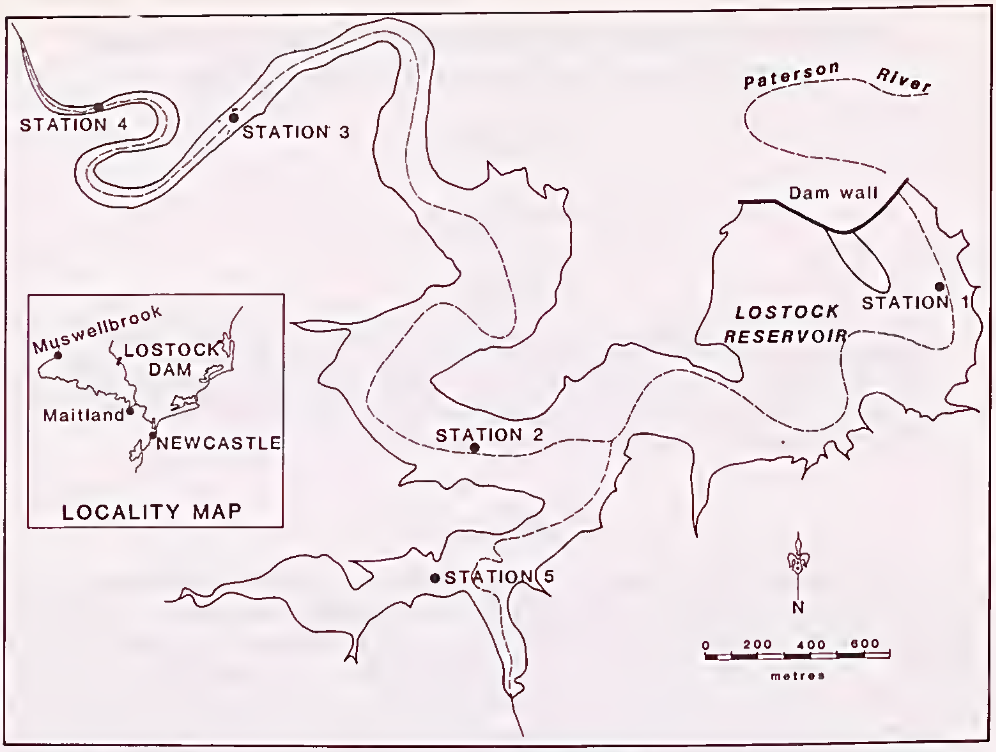

Figure 1. Location of Lostock Dam in Hunter River Valley, showing locations of collecting stations.

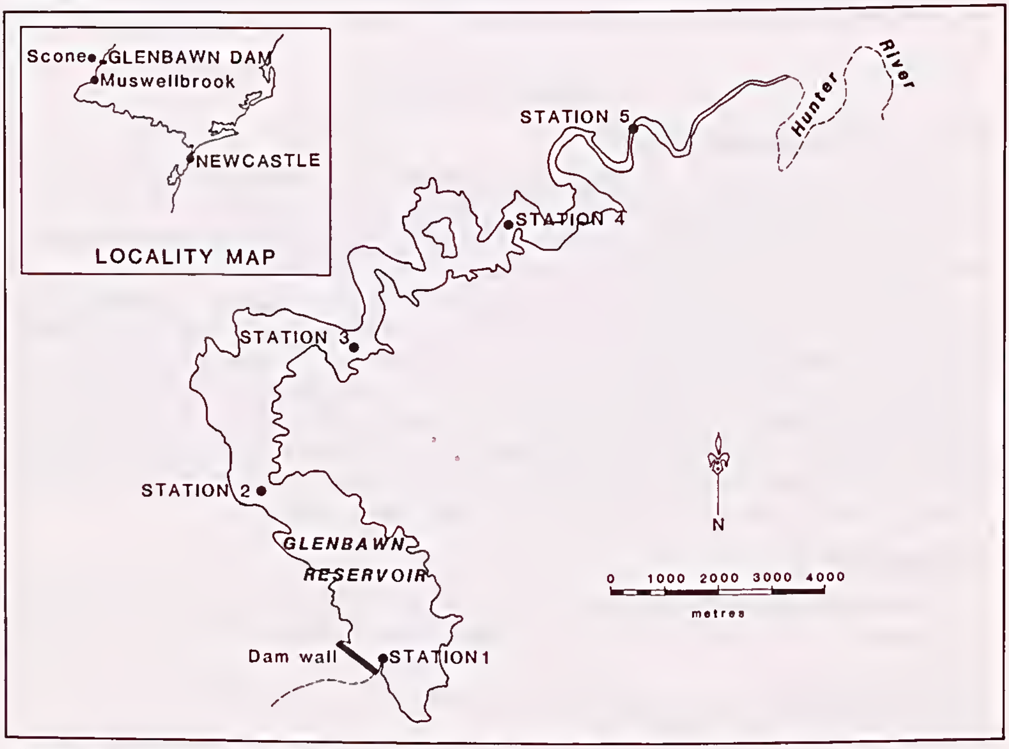

Figure 2. Location of Glenbawn Dam in Hunter River Valley, showing locations of collecting stations.

development in the first two years, but less so in the third (drought). This decreased seasonality in drought time was also recorded in the Peel River (May & Powell, 1986). The lack of precise seasonality in Glenbawn and Lostock is probably due to variations in year-to-year temperatures and inorganic nutrients, though many species tend to occur more often in summer (Table 1, Seasonal Effect).

Drought

The major effect of drought (1980–81) in Lostock (Table 1, Effect of drought) was immediately to increase the frequency of 22 common taxa, with a further three taxa remaining near their maximum frequency during the drought. Nine taxa continued to show increased frequency in the year following the drought. Those remaining of the original taxa showed a slight or marked reduction in frequency during the drought or were erratic.

In eight common taxa in Glenbawn, frequency stayed constant or increased with drought and continued at high or even increasing levels in the prolonged drought[3]. In another 10 species the frequency at first increased with drought, then decreased with prolonged drought (Table 1, Effect of drought). In contrast, 12 taxa decreased with drought and continued at low or even decreasing frequencies thereafter, while another two decreased in frequency with drought and later increased with prolonged drought. Two taxa showed less clear changes.

Fifteen of the 30 common taxa occurring in both dams increased in frequency of occurrence with the onset of drought, two others also increased, but, in Glenbawn, only after an initial decrease. Eight other taxa decreased in both dams and one showed no significant change (Table 1, Effect of drought). Thus, only four taxa showed contrasting behaviour, increasing in frequency at the onset of drought at Lostock, but decreasing at Glenbawn.

There appears to be little relationship between the after-effects of drought shown at Lostock and the response of various species to prolonged drought at Glenbawn (Table 1, Effect of drought). Although more taxa showed high abundance ratings more often in drought time, only two taxa (*Sphaerocystis* and *Peridinium*) became abundant in both dams during drought or prolonged drought. The number and occurrences of rare species increased with drought in both dams, but then decreased with prolonged drought at Glenbawn. Drift species were less frequent in times of poor water flow.

Comparing Carcoar (May, 1988), Lostock and Glenbawn, six common taxa (*Botryococcus*, *Closterium aciculare*, *Ceratium*, *Microcoleus*, *Pediastrum duplex* and *Trachelomonas armata*) increased or extended their range in some way with the onset of drought in all three dams; only *Melosira varians* decreased in all three.

Position of station

Some taxa were more frequent upstream and probably represent what have been termed 'fluvial' species, while those with lower frequency upstream are regarded as 'lacustrine' species[4].

Nine common taxa appeared as fluvial species in both dams while another eight were lacustrine (Table 1, Behaviour). Four taxa had contrasting behaviour; some species showed definite behaviour in one dam, indefinite in the other. A comparison of common lacustrine and fluvial taxa found in all or combinations of Chaffey, Carcoar, Lostock and Glenbawn Dams is shown in Table 2.

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[3] *Anacystis* is included here; already very high in freqency, it increased progressively in abundance.

[4] *Anabaina* and *Euglena* sp. 2 are also considered as fluvial in Glenbawn dam, since they occurred in abundance or high abundance much more frequently in Stations 4 and 5.

Table 1: Frequency of occurrence, seasonality, abundance, fluvial or lacustrine behaviour and effect of drought on species recorded from Lostock (LO) and Glenbawn (GL) Dams.

Taxon	1 Frequency		2 Seasonal effect		3 Abundance		4 Behaviour		5 Effect of drought		
Dam:	LO	GL	LO	GL	LO	GL	LO	GL	LO	GL	Comp.
Actinastrum hantzschii Lag.	C	C	Jan	Nov, Jan, Feb	1	—	F	F	I+	D+	X
Agmenellum thermale (Kuetz.) Drouet & Daily	R	—	—	—	—	—	—	—	—	—	—
Anabaina circinalis Rabenh.	C	C	Jan–Apr, Oct	Jan	1	2	L	F	(D)	D+	D
Anacystis cyanea (Kuetz.) Drouet & Daily (= *Microcystis aeruginosa* Kuetz.)	C	C	Feb, Apr, May, Oct	Jan–Feb, Apr, Jun–Aug	—	2	L	L	I+	I+	1
Ankistrodesmus falcatus (Corda) Ralfs	C	C	May, Jul, Aug, Oct	Oct, Dec	—	1	F	L	(I)	i+	1
Aphanizomenon (ecophene of *Calothrix parietina* (Naeg.) Thuret)	R	C	—	Jan	—	1	—	L	—	D+	—
Asterionella sp.	C	—	Dec	—	2	—	L	—	(I)	—	—
Botryococcus braunii Kuetz.	C	C	Dec	Jan, Feb, Jun	2	—	L	L	(I)	I+	I
Ceratium hirundinella (O.F. Muell.) Dujardin	C	C	Apr, Jun	Apr, Jun	1	1	L	L	(I)	D+	X
Chlamydomonas sp.	—	R	—	—	—	—	—	—	—	—	—
Chodatella chodati (Bern.) Ley.	R	—	—	—	—	—	—	—	—	—	—
C. subsalsa Lemm. (*Lagerheimia*)	R	C	—	Jan, Dec	—	2	—	—	—	(I)	—
Cladophora crispata (Roth) Kuetz.	D	D	—	—	—	—	—	—	—	—	—
Closterium aciculare T. West	C	C	Oct, Dec	Mar, Apr, Jun, Sep, Oct	—	1	L	L	(I)	(i)	I
C. acutum (Lyngb.) de Bréb.	C	C	Aug, Oct	Nov	—	1	L	L	(I)	I+	I
C. parvulum Naeg.	R	C	—	Jul, Sep	—	—	—	—	—	d+	—

C. sp. 1	R	R	—	—	—	—	—	—	—	—	—
C. sp. 3	—	R	—	—	—	—	—	—	—	—	—
Cosmarium sp.	C	R	May	—	—	—	—	—	(I)	—	—
Crucigenia rectangularis (Braun) Gay	C	R	Feb	—	—	—	F	—	(i)	—	—
Cyclotella meneghiniana Kuetz.	C	C	Feb, Dec	Feb, Aug, Oct, Nov	—	1	F	F	(I)	D+	X
Diacanthos belenophorus Korch.	R	—	—	—	—	—	—	—	—	—	—
Diatoms (undetermined species)	C	C	Aug, Sep, Nov	Jan	1	1	F	F	d+	D+	D
Dictyosphaerium pulchellum Wood	—	R	—	—	—	—	—	—	—	—	—
Dinobryon sertularia Ehrenb.	C	—	Oct, Dec	—	2	—	F	—	(I)	—	—
Eudorina elegans Ehrenb.	R	R	—	—	—	—	—	—	—	—	—
Euglena acus Ehrenb.	—	R	—	—	—	—	—	—	—	—	—
E. polymorpha Dang.	C	C	May–Jul, Feb, Oct	Jan–Mar, Jun	1	1	F	F	d+	D+	D
E. aff. *tripteris* (Dujardin) Klebs	—	R	—	—	—	—	—	—	—	—	—
E. sp. 1	R	—	—	—	—	—	—	—	—	—	—
E. sp. 2	C	C	Jan, Aug	Dec	—	1	F	F	i+	i+	—
E. sp. 3	C	—	Jun, Aug	—	—	—	—	—	—	—	—
Glenodinium sp.	R	—	—	—	—	—	—	—	—	—	—
Golenkinia sp.	R	—	—	—	—	—	—	—	—	—	—
Gonium pectorale Muell.	R	R	—	—	—	—	—	—	—	—	—
Hydrodictyon reticulatum (L.) Lag.	R	R	—	—	—	—	—	—	—	—	—
Lepocinclis sp.	R	—	—	—	—	—	—	—	—	—	—
Melosira granulata (Ehrenb.) Ralfs	C	C	Jan	Nov–Jun	2	2	—	F	I+	(I)	I
M. variana Ag.	C	C	May, Oct	Feb	—	—	F	F	d+	D+	D
Micractinium pusillum Fres.	—	R	—	—	—	—	—	—	—	—	—
Microcoleus lyngbyaceus (Kuetz.) Crouan	C	C	Apr	Feb	—	—	—	F	(i)	I+	I
Mougeota sp.	—	D	—	—	—	—	—	—	—	—	—
Nephrocytium agardianum Naeg.	C	C	Jul, Aug, Oct, Nov	Feb	1	—	—	—	(I)	(I)	I
Nodularia sp.	R	—	—	—	—	—	—	—	—	—	—
Oedogonium sp.	D	—	—	—	—	—	—	—	—	—	—
Oocystis gigas Archer	C	C	Mar, Apr, Aug	Nov	1	1	L	L	I+	D+	X

Taxon	1 Frequency		2 Seasonal effect		3 Abundance		4 Behaviour		5 Effect of drought		
Dam:	LO	GL	LO	GL	LO	GL	LO	GL	LO	GL	Comp.
O. parva West & West	C	C	Apr, Sep	Oct	—	—	L	L	I+	(I)	I
Oscillatoria ? *lutea* Ag.	C	C	Apr, Jun, Oct	Mar–May	—	—	—	F	D+	D+	D
Pandorina morum (Muell.) Bory	C	C	Dec	Jan	—	—	F	F	d+	(D)	D
Pediastrum boryanum (Turp.) Meneghini	R	R	—	—	—	—	—	—	—	—	—
P. duplex Meyen	C	C	Dec	Jan, Jul	—	—	F	F	(I)	(I)	I
Peridinium granulosum P'fair	C	C	Mar	Jan, Feb, Apr	1	1	L	L	(I)	(I)	I
Phacus caudatus Huebner	R	R	—	—	—	—	—	—	—	—	—
P. sp.	R	—	—	—	—	—	—	—	—	—	—
Pleurotaenium sp.	R	—	—	—	—	—	—	—	—	—	—
Scenedesmus abundans (Kirchner) Chodat	—	R	—	—	—	—	—	—	—	—	—
S. bijugus (Turp.) Kuetz.	C	C	Oct	Jan	—	—	—	—	(I)	(I)	I
S. obliquus (Turp.) Kuetz.	R	R	—	—	—	—	—	—	—	—	—
S. quadricaudus (Turp.) de Bréb.	R	C	—	Jan	—	—	—	F	—	—	—
Schizothrix calcicola (Ag.) Gomont	C	C	Dec	Jan	—	—	L	F	D+	D+	D
Schroederia judayi G. M. Smith	C	C	Apr–Jun, Aug	Dec	—	—	—	—	I+	See Text	
Sphaerocystis schroeteri Chodat	C	C	Dec	Jan	2	2	—	F	I+	See Text	
Spirogyra sp.	D	D	—	—	—	—	—	—	—	—	—
Spirulina subsalsa Oersted	R	—	—	—	—	—	—	—	—	—	—
Staurastrum pingue Teiling	C	C	Sep	Jun	2	1	—	L	I+	(I)	I
Stigeoclonium sp.	D	—	—	—	—	—	—	—	—	—	—
Synura adamsii G. M. Smith	C	R	Jul	—	1	—	F	—	D+	—	—
Tetraëdron hastatum (Reinsch.) Hansgirg	R	—	—	—	—	—	—	—	—	—	—

T. minimum (A. Braun) Hansgirg	—	R	—	—	—	—	—	—	—	—	—
T. trigonum (Naeg.) Hansgirg	R	—	—	—	—	—	—	—	—	—	—
Tetraspora lubrica (Roth) Ag.	R	R	—	—	—	—	—	—	—	—	—
Trachelomonas armata (Ehrenb.) Stein	C	C	Jan, Feb	Apr, Jul, Nov–Jan	1	—	F	L	(I)	I+	I
T. girardiana (P'fair) Deflandre	R	R	—	—	—	—	—	—	—	—	—
Trachelomonas hispida (Perty) Stein	C	C	Jan, Mar, Jun, Sep	Jun, Aug, Oct–Jan	1	1	L	—	(I)	(i)	I
T. sp.	R	—	—	—	—	—	—	—	—	—	—
Ulothrix sp.	D	—	—	—	—	—	—	—	—	—	—
Volvox globator L.	C	C	Mar, Oct	Sep	1	1	F	F	(D)	(D)	D
Zygnema sp.	—	D	—	—	—	—	—	—	—	—	—

1. Frequency (all species). C = common species (>5%). R = rare species (≤5%). D = drift species.

2. Seasonal Effect (common species). Showing months of occurrence at most stations.

3. Abundance (common species). 1 = medium abundance rating. 2 = high abundance rating.

4. Behaviour (common species). F = Fluvial (more common at upstream stations). L = Lacustrine (more common at downstream locations).

5. Effect of Drought (common species). A frequency change of over 5% is considered significant and is shown by a capital letter; lesser changes are shown in lower case. I = Frequency increased with drought or remained high during drought. (I) = Increase in frequency occurred only or mainly in year of drought. I+ = Increased frequency continued or became greater in year following drought. D = Frequency decreased with drought. (D) = Decrease in frequency occurred only or mainly in year of drought. D+ = Decreased frequency continued or became lower in year following drought.
Comp. — Comparison between the response of species common to Glenbawn and Lostock Dams. I = Increase common to both dams. D = Decrease common to both dams. X = Responses of species differ between dams. A common result is accepted when the figures for one or both dams reach significance and the trend is the same in both dams.

Table 2: Number of common lacustrine and fluvial species found in four dams. (Figures from present paper, May & Powell 1986 and May 1988).

	Chaffey Carcoar Lostock Glenbawn	Carcoar Lostock Glenbawn	Chaffey Lostock Glenbawn	Chaffey Carcoar Glenbawn	Lostock Glenbawn
Lacustrine	3	6	4	4	8
Fluvial	0	1	2	0	9

Drift and rare species were found more often in mid- and upstream stations of both Lostock and Glenbawn Dams, but there were fewer occurrences of medium or high abundance ratings in other species and fewer taxa exhibiting this behaviour in the upstream stations.

Depth

Both dams showed greater frequency of occurrence and of abundance of most taxa at most times in surface water, as was found at Chaffey and Carcoar Dams (May & Powell, 1986; May, 1988). Only *Melosira granulata* showed greater frequency of occurrence (in both dams) and of abundance (in Glenbawn) in bottom collections. Bowen & Small (1980) describe *Melosira granulata* blooming after circulation of filaments from the hypolimnion.

In contrast with the importance of algae in top water, Wiederholm (1973) found bottom fauna provided indicator organisms of ecological significance.

Drought and position of station

Of the eight common lacustrine species found in both Lostock and Glenbawn, six increased in frequency with drought; of the nine common fluvial species found in both dams, five decreased in frequency with drought, while only one increased (Table 1, Effect of Position of Station and of Drought). This indicates that fluvial taxa are, in general, more adversely affected by drought. The four taxa that responded differently to drought in the two dams are probably affected more by some other, as yet undetermined, factor.

Physicochemical results

From surface water data obtained from Glenbawn Dam by the Water Resources Commission, it can be shown that turbidity, ammonia and iron, and possibly total phosphorus, increased with both position upstream and drought, while carbonate decreased correspondingly. Nitrate increased with prolonged drought (in both surface and bottom water), but not with progress upstream.

It has been shown above that the fluvial taxa tend to be more adversely affected by drought than do lacustrine taxa. Thus, with an apparently adequate annual nutrient supply, those physicochemical factors which act in the same way with both position in dam and drought do not determine which taxa thrive at each place. However, as nitrate increased with prolonged drought but not with position of station, it seems likely that this could be important in determining the changes in distribution of some taxa with prolonged drought.

At Glenbawn Dam, during the drought times *Anacystis* gradually replaced *Anabaina* as the toxic alga of greater occurrence and abundance. Since this time interval is associated with increasing nitrate content this observation supports the results reported from Carcoar Dam (May, 1988) showing that the concentration of oxidised nitrogen determines which of these blue-green algal species is likely to occur in quantity.

Acknowledgements

These studies were carried out as part of the continuing study of water quality in New South Wales storages being undertaken by the Water Resources Commission of New South Wales, to whom I am grateful for collecting the water samples and for other assistance. I would also like to thank Mr. Andrew Mitchell for welcome editorial assistance.

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Appendix 1

Species recorded from Lostock (marked L) and Glenbawn Dams (marked G)

LG *Actinastrum hantzschii* Lag.
L *Agmenellum thermale* (Kuetz.) Drouet & Daily
LG *Anabaina circinalis* Rabenh.
LG *Anacystis cyanea* (Kuetz.) Drouet & Daily (= *Microcystis aeruginosa* Kuetz.)
LG *Ankistrodesmus falcatus* (Corda) Ralfs
LG *Aphanizomenon* (ecophene of *Calothrix parietina* (Naeg.) Thuret)
L *Asterionella* sp.
LG *Botryococcus braunii* Kuetz.
LG *Ceratium hirundinella* (O.F. Muell.) Dujardin
G *Chlamydomonas* sp.
L *Chodatella chodati* (Bern.) Ley.
LG *C. subsalsa* Lemm. (*Lagerheimia*)
LG *Cladophora crispata* (Roth) Kuetz.
LG *Closterium aciculare* T. West
LG *C. acutum* (Lyngh.) de Bréb.
LG *C. parvulum* Naeg.
LG *C.* sp. 1
G *C.* sp. 3
LG *Cosmarium* sp.
LG *Crucigenia rectangularis* (Braun) Gay.
LG *Cyclotella meneghiniana* Kuetz.

L	*Diacanthos belenophorus* Korch.
LG	Diatoms (undetermined species)
G	*Dictyosphaerium pulchellum* Wood
L	*Dinobryon sertularia* Ehrenb.
LG	*Eudorina elegans* Ehrenb.
G	*Euglena acus* Ehrenb.
LG	*E. polymorpha* Dang.
G	*E.* aff. *tripteris* (Dujardin) Klebs
L	*E.* sp. 1
LG	*E.* sp. 2
L	*E.* sp. 3
L	*Glenodinium* sp.
L	*Golenkinia* sp.
LG	*Gonium pectorale* Muell.
LG	*Hydrodictyon reticulatum* (L.) Lag.
L	*Lepocinclis* sp.
LG	*Melosira granulata* (Ehrenb.) Ralfs
LG	*M. varians* Ag.
G	*Micractinium pusillum* Fres.
LG	*Microcoleus lyngbyaceus* (Kuetz.) Crouan
G	*Mougeota* sp.
LG	*Nephrocytium agardianum* Naeg.
L	*Nodularia* sp.
L	*Oedogonium* sp.
LG	*Oocystis gigas* Archer
LG	*O. parva* West & West
LG	*Oscillatoria ? lutea* Ag.
LG	*Pandorina morum* (Muell.) Bory
LG	*Pediastrum boryanum* (Turp.) Meneghini
LG	*P. duplex* Meyen
LG	*Peridinium granulosum* P'fair
LG	*Phacus caudatus* Huebner
L	*P.* sp.
L	*Pleurotaenium* sp.
G	*Scenedesmus abundans* (Kirchner) Chodat
LG	*S. bijugus* (Turp.) Kuetz.
LG	*S. obliquus* (Turp.) Kuetz.
LG	*S. quadricaudus* (Turp.) de Bréb.
LG	*Schizothrix calcicola* (Ag.) Gomont
LG	*Schroederia judayi* G. M. Smith
LG	*Sphaerocystis schroeteri* Chodat
LG	*Spirogyra* sp.
L	*Spirulina subsalsa* Oersted
LG	*Staurastrum pingue* Teiling
L	*Stigeoclonium* sp.
LG	*Synura adamsii* G. M. Smith
L	*Tetraëdron hastatum* (Reinsch.) Hansgirg
G	*T. minimum* (A. Braun) Hansgirg
L	*T. trigonum* (Naeg.) Hansgirg
LG	*Tetraspora lubrica* (Roth) Ag.
LG	*Trachelomonas armata* (Ehrenb.) Stein
LG	*T. girardiana* (P'fair) Deflandre
LG	*Trachelomonas hispida* (Perty) Stein
L	*T.* sp.
L	*Ulothrix* sp.
LG	*Volvox globator* L.
G	*Zygnema* sp.

Understorey changes following fire at Myall Lakes, New South Wales

M.D. Fox

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Abstract

Fox, M.D. (National Herbarium of New South Wales, Royal Botanic Gardens, Australia 2000) 1988. Understorey changes following fire at Myall Lakes, New South Wales. Cunninghamia 2(1): 85-95. — Changes in understorey structure and composition of a series of 60 stands ranging in age from 1 month to 16 years since fire were examined at Myall Lakes National Park, New South Wales. Of the 122 vascular species encountered, 47% were obligate seedling regenerators while the remainder were vegetative regenerators. Height increased linearly with time and understorey cover re-established rapidly (due largely to *Pteridium esculentum* in the early years). Species richness was high immediately after fire, peaked at about 36 species after four years, dropped substantially at about ten years to climb to 39 species after 16 years. In contrast, plant species diversity peaked at about ten years and had dropped appreciably by 16 years.

Introduction

Fire is a conspicuous force in many Australian ecosystems and the literature on its effects on the biota is large (Gill, Groves & Noble 1981, and cited literature). However, there have been relatively few studies at the community level of the changes following fire. Classification of plant species by the mode of regeneration after fire has been used for at least 50 years, but few analyses of community composition using such classifications have been published.

This study was designed to analyse the response of a plant community to fire by considering the changes in composition of an open-forest understorey. The changes were assessed from the community attributes of species richness, diversity, and cover, as well as from a consideration of the mode of regeneration of the species. The study area was selected because it combined a relatively uniform substrate supporting a forest with different aged patches of regenerating understorey. Samples were taken in patches with different ages since fire. The same sampling technique has been used to monitor regeneration after sand-mining in the same forest (Fox & Fox 1984) and in nearby heathland (Fox & Fox 1978).

The study area

The forest grows on nutrient-poor Holocene sand near Seal Rocks (32°41′S, 152°09′E) in the Myall Lakes National Park, New South Wales. Seal Rocks is the northern limit of a triple embayment system bounded to the south by Hawkes Nest (Thom 1965). The sediment in the embayments is siliceous sand, the older Pleistocene horizon being heavily humate-impregnated and indurated, while the more recent Holocene deposits are in places lightly podzolized. In the Seal Rocks embayment the Holocene sand forms large transgressive sheets that have mantled the older surface. The northern and westward extent of this transgressive sheet is a high, long-walled ridge, Bridge Hill Ridge, which is in places over 100 m high.

The area experiences equable temperatures and some rain can be expected in every month (1352mm, 30 year annual average 1948–77, Sugarloaf Point 32°26′S, 152°32′E) with a peak in late autumn and early winter and moisture deficits through spring and summer.

The sand surface is forested with trees from 20 to 30 m tall having a basal area of about 25m^2 ha^{-1} and canopy cover of about 65% (Fox 1981). The main tree species are *Eucalyptus pilularis* Sm (MAIAA — code according to Pryor & Johnson 1971) and *Angophora costata* (Gaertn.) Druce (AAAD). The understorey is of scleromorphic shrubs, grasses, ferns and some herbs.

The forest is frequently burnt. For the 18 years preceding and encompassing this study, parts of the forest had burnt 15 times (Table 1). Some fires were both extensive and intense, burning several thousand hectares and incinerating the canopies of the eucalypts. However, many others were localized and of low intensity, burning only a few hundred hectares and possibly not even scorching the canopy. The latter kind were often the result of human activities in the area. It is likely that the 'natural' (pre-settlement) fire regime was of less frequent but more intense fires (Walker 1981). Myall Lakes falls within Walker's Fire Region 11, which has a fire interval of 5–15 years.

The fire season for this region is from mid-October to the end of January (Walker 1981). The more extensive fires in the past 18 years have been predominantly spring and summer fires (September 1980; October 1971, 1974, 1977, 1979, 1981; November 1968, 1980; January 1976, 1982; February 1975, 1979). There have also been winter fires (August 1974, 1980, 1984). The most severe (in extent and intensity) were the October 1968, January 1976 and August 1980 fires. The season of fires is important to the community regeneration in terms of the phenology of the individual species.

Table 1: The dates of 15 fires reported in the forest for the period November 1968 to August 1984. The numbers of sites and their ages at sampling (in brackets, years) for the four survey periods are shown.

Date of Fire		Date of Survey* Sept.–Dec. 1976	Nov. 1977	Feb. 1982	Mar. 1985
November	1968	1 (8.0)	1 (9.0)	n.s.	3 (16.3)
October	1971	6 (5.0)	n.s.	n.s.	n.s.
August	1974	7 (2.2)	n.s.	n.s.	n.s.
October	1974	2 (1.9)	1 (3.1)	n.s.	2 (10.4)
February	1975	1 (1.5)	n.s.	n.s.	n.s.
January	1976	24 (0.8)	2 (1.8)	n.s.	n.s.
October	1977	—	n.s.	n.s.	1 (7.4)
February	1979	—	—	2 (3.0)	n.s.
October	1979	—	—	n.s.	n.s.
August	1980	—	—	n.s.	n.s.
September	1980	—	—	n.s.	n.s.
November	1980	—	—	3 (1.3)	1 (4.3)
October	1981	—	—	n.s.	n.s.
January	1982	—	—	2 (0.1)	n.s.
August	1984	—	—	—	1 (0.5)

* n.s. = not sampled

The effects of fire in this forest have been studied for litter accumulation (Fox, Fox & McKay 1979), and small mammal and vegetation regeneration (Fox & McKay 1981). The effects of fire frequency on the floristic composition and structure of woodland in the adjacent Eurunderee embayment (Fox & Fox 1986) have also been investigated.

Methods

In order to study the changes occurring as the community responds to the conditions after fire, a range of sites with different fire histories was used. Data were collected on four occasions spanning 8.5 years from a total of 60 sites, covering a range of ages since fire from one month to over 16 years. Table 1 lists the dates of the 15 fires recorded in the forest for a 16 year period and the number and ages of sites sampled. Because of the high frequency of fires in the forest, many samples were less than a year since fire (n = 27), eight were from one year to two years, 14 from two years to five years, six were between five and ten years, and five were more than ten years. The first set of 45 sites was strongly biased to sites less than a year old because of the extensive fire in January 1976. For this reason subsequent sampling concentrated on older sites of known age.

Figure 1 shows the location of the study sites, mostly south of the Seal Rocks road in an area of 2700 ha of open-forest. Initially 45 sites (numbered 1 to 45) were located on a 500 m grid and sampled in 1976 and 1977 (Fox 1981), with an additional seven sites (46 to 52) located on a transect from the high ridge to the sea (1982), while the 1985 sites (53 to 60) were largely selected to sample sites that had not then burnt for over ten years.

At sites 1 to 45 a quadrat of 0.04 ha (4 x 100 m) was used. The other 15 sites used a larger quadrat (20 x 100 m) to be consistent with data collected from a variety of other communities. All vascular plant species in the understorey (including small trees such as *Banksia serrata* and *Xylomelum pyriforme)* within each quadrat were recorded as the species richness for that site. The sixty sites were grouped into 12 age classes, segregating the smaller and larger quadrat sizes.

At each site the cover of understorey species was measured as line intercepts on a 100 m transect. The height of the understorey was measured at ten points along the transect and a mean value for the site calculated. Both height and cover measurements were independent of quadrat size and were grouped into ten age classes. Using cover values as measures of abundance, species diversity was calculated as the inverse of Simpson's (1949) index of concentration:

$$\Delta_3 = (\Sigma p_i^2)^{-1}$$

where p_i is the proportion of species i in the sample (Hurlbert 1971). Because diversity incorporates richness, the same twelve age classes were used as were distinguished for the richness data.

All vascular plant species occurring in the 60 sites were classified into one of the seven regeneration categories recognized by Gill (1975, 1981), based on observation in the field or consultation with colleagues. In some cases it was evident that some individuals of a species, otherwise considered to be an obligate seeder, may survive a low intensity fire and show vegetative growth from existing structures. Conversely examples of vegetative regenerators occasionally being killed by fire were also observed. All of the vegetative regenerators (categories IV, V, VI and VII) are also facultative seedling regenerators. In all such cases the usual (i.e. the population's) mode of regeneration after fire in the Seal Rocks open-forest was recorded for the species (see Appendix I). The seven regeneration categories (from Gill 1975) are:

I Mature plant killed by fire, seed stored on plant.
II Mature plant killed by fire, seed stored in soil.
III Mature plant killed by fire, seed storage absent.
IV Mature plant survives, sprouts from root suckers or horizontal rhizomes.
V Mature plant survives, sprouts from basal stem or vertical rhizome.
VI Mature plant survives, sprouts from aerial epicormic buds.
VII Mature plant survives, sprouts from undamaged buds that were active pre-fire.

Species fitting the first three categories are sometimes referred to as fire-sensitive species or as obligate seedling regenerators, the other four categories contain fire-resistant species, also referred to as vegetative regenerators or resprouters. At each site the percentage contributions to total richness of fire-sensitive species and fire-resistant species were calculated, and the percentage of total cover of each type also calculated.

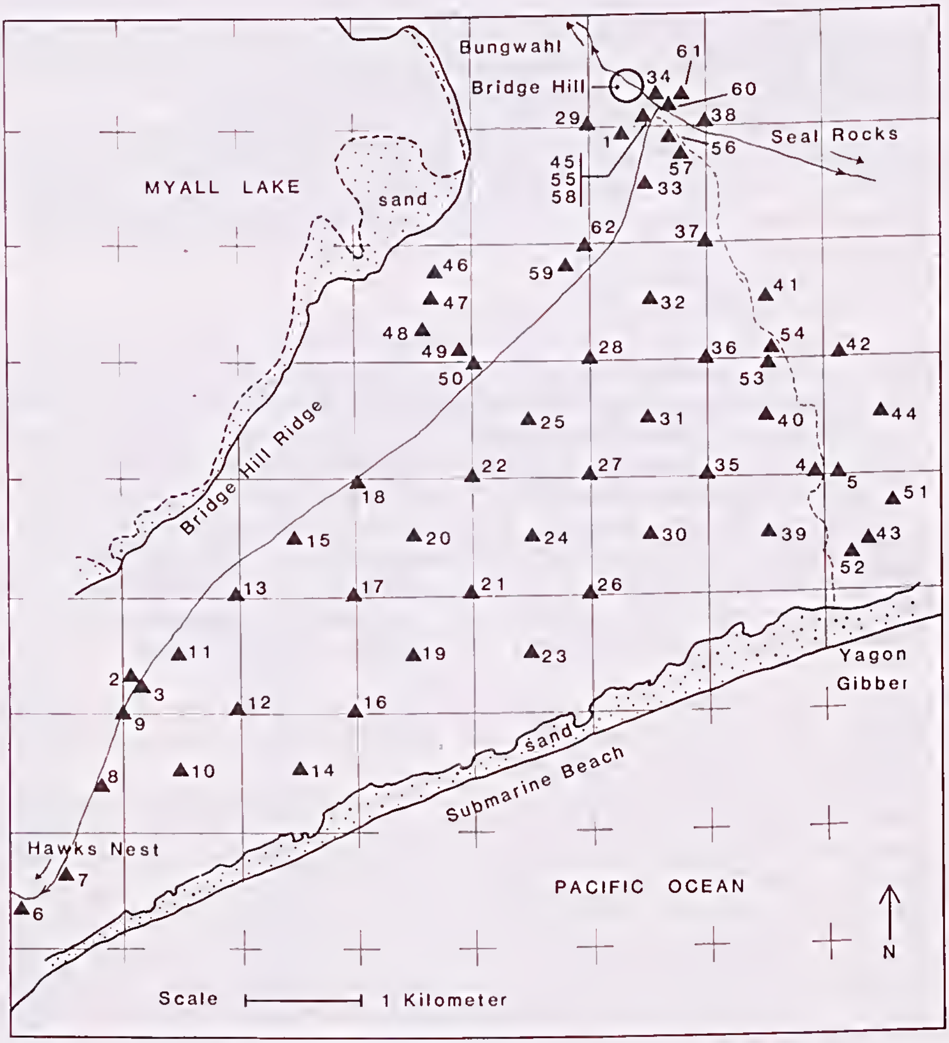

Figure 1. The location of the sixty sites covering approximately 2700ha of open-forest in Myall Lakes National Park.

Results

There is a statistically significant linear increase in the height of the understorey with time since fire ($n = 60$, $r = 0.9764$, $p < 0.001$). Figure 2 shows mean values for ten age classes with the regression line calculated from the 60 individual values. Sixteen years after fire the understorey was four metres tall.

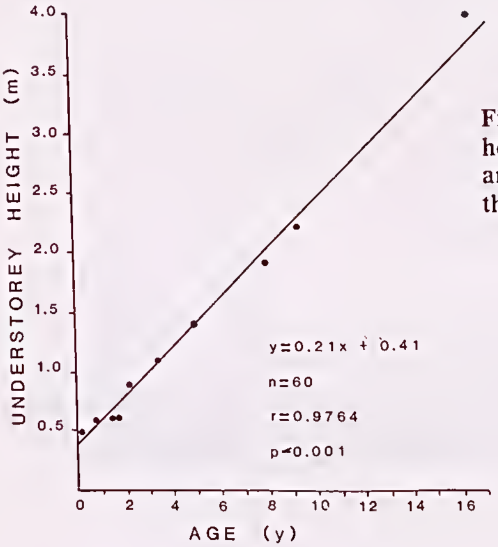

Figure 2. The linear increase in understorey height with time since fire. The points shown are the mean values for ten age classes; the line is the regression for the 60 sites.

One hundred and twenty two vascular plant species were encountered in the 60 sites (Appendix I). The average richness (+/– S.E.) of the sites was 34.8 +/– 0.7 [range 22–50]. There was no significant difference between the richness of the 0.04 ha plots ($\bar{x} = 34.7$ +/– 0.8 species, $n = 45$) and the larger plots ($\bar{x} = 34.8$ +/– 0.9 species, $n = 15$).

Figure 3 shows species richness as a function of time since fire. The mean number of species per site for 12 age classes is shown. There is a slight peak at four years, then a decline and then a rise to 39 species after 16 years. The data points can be fitted to a significant third order polynomial equation ($r = 0.2665$, 56 d.f., $p < 0.05 = 0.255$) which is the curve illustrated. Because of the high variability or 'noise' in the system, indicated by the magnitude of the standard error bars, only 7.1% of the variance is accounted for, but this is significantly better than a linear fit. This confirms that the drop in species richness at ten years and the second peak are real features. There are significantly more species after 16 years than immediately after fire ($t = 3.84$, d.f. $= 4$, $p < 0.02$).

Figure 4 shows the mean values for plant species diversity for the same age classes. These begin at values close to 3.0 but rise to peak at about 9.0 after ten years, and then drop substantially by 16 years after fire. The individual points demonstrate a significant fit to a quadratic equation ($r = 0.648$, $p < 0.005$) which explains 42% of the variance in plant species diversity and models the increase and subsequent decrease.

There is a significant negative correlation between species diversity and the amount of *Pteridium esculentum* cover ($r = -0.7041$, $n = 60$, $p < 0.001$).

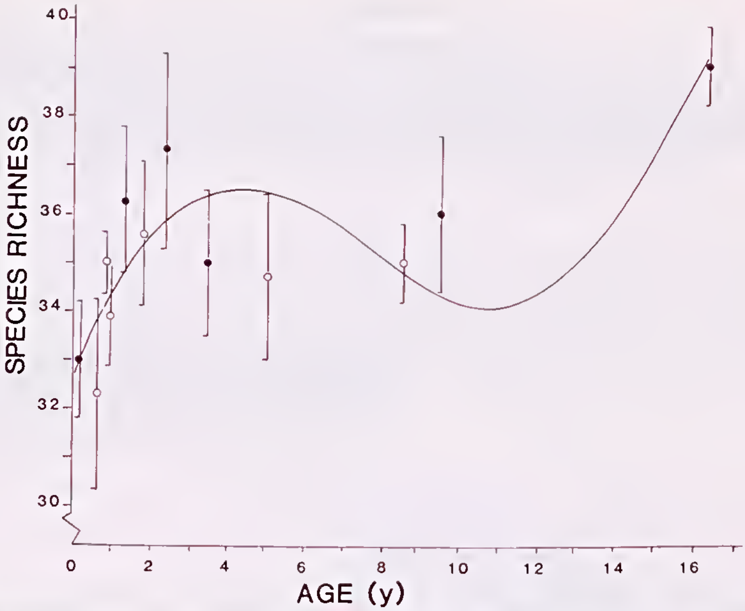

Figure 3. Changes in species richness with time since fire. The means (+/− standard error of the mean) for twelve age classes are shown. Open symbols are 0.04ha and closed symbols 0.2ha quadrats. The curve is a significant cubic function fitted to the 60 data points.

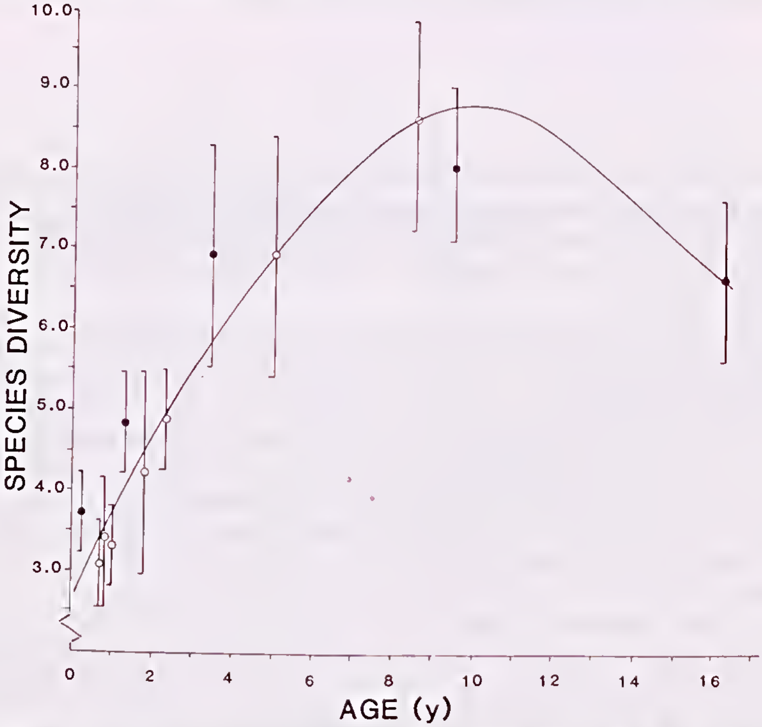

Figure 4. Changes in plant species diversity as a function of time since fire. The means (+/− standard error of the mean) for twelve age classes are shown. Open symbols are 0.04ha and closed symbols 0.2ha quadrats. The curve is a highly significant quadratic function fitted to the 60 data points.

Total understorey cover (Figure 5) returns to quite high values soon after fire, due largely to the rapid response of *Pteridium esculentum*. Cover tends to increase to peak values in the five to ten year period after fire and then to decline slightly. The greater part of the cover is contributed by the resprouting species. There is some fluctuation in the amount of cover from the vegetative regenerators, caused primarily by a second peak in *Pteridium* cover at five years.

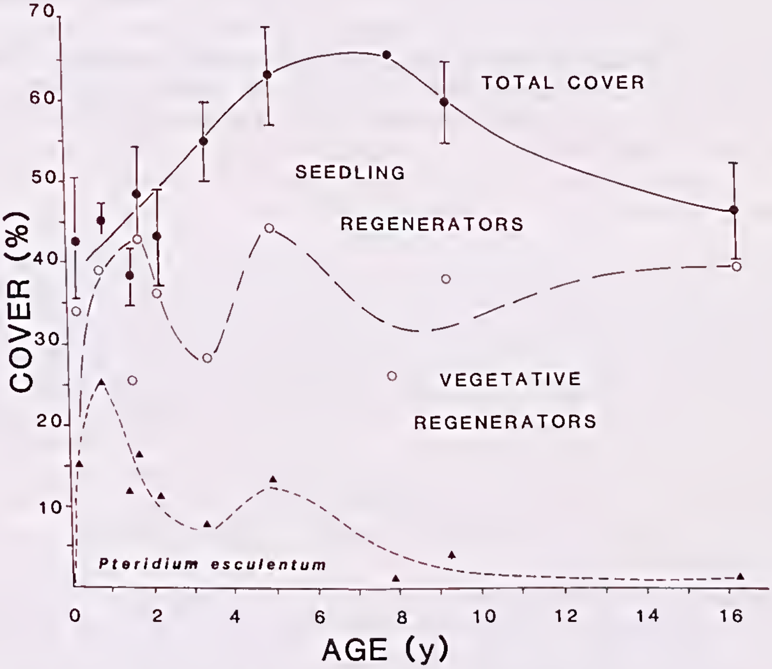

Figure 5. Changes in total cover partitioned into seedling and vegetative regenerators (with *Pteridium esculentum* shown separately) with time since fire. The same age classes are used as in Figures 2 and 3.

When the percentages of obligate seedling and vegetative regenerators are compared, these are remarkably constant with time since fire. The proportion of vegetative regenerators is approximately 61% from 0.3 years to 16.3 years. However, the percentage cover of these regeneration types fluctuates more widely. For the first five age classes (to 2.2 years) over 70% of total cover is provided by the resprouting species, this fluctuates widely between 40 and 80% for the next seven years and by 16 years returns to about 85%.

Only one species was classified as retaining seed on the plant (I, *Banksia integrifolia*), although elsewhere it resprouts from epicormic buds and seed is released when mature; and one as having no seed storage (III, *Senecio lautus*). Of the large number of species in category II (seed stored in soil), many retain some seed on the plant for some time, but ultimately it is shed. Of the vegetative regenerators, most belong to category V (sprouts from basal stem or vertical rhizome), with fewer in categories IV and VI, and only three species in category VII (sprouting from undamaged buds active pre-fire). Of the total of 122 species, 47% are in categories I, II and III (the obligate seedling regenerators) while 53% are in the vegetative categories (IV, V, VI and VII).

Discussion

The Myall Lakes area may have a natural fire interval of 5–15 years (Walker 1981), so the sites that are 16.3 years old are close to the maximum for coastal eucalypt forest. Fuel loads for Fire Region 11 vary from 0.35–2.00 kg m^{-2}; Fox *et al.* (1979) estimated the litter steady-state for the Seal Rocks forest is 1.67 kg m^{-2}. This is at the higher end of the fuel range which in turn would lead to higher fire frequency. This is supported by a recent study indicating that the period between fires in this area probably falls in the 6–12 year range (Fox & Fox 1986) and by the litter steady-state which is reached after about ten years (Fox *et al.* 1979). Anthropogenic fires have increased this natural frequency for much of the forest to about every four years; the much older sites are small relict patches.

For at least the preceding 16 years the oldest sites have experienced only one fire while the younger sites have been burnt several times. This may introduce a factor which differentiates the sites and confounds the previous assumption of homogeneity. In woodland in the adjacent Eurunderee embayment, an area that had burnt twice in 12 years had significantly more species, greater shrub density and greater cover than an adjacent area that had only burnt once (Fox & Fox 1986).

The changes in diversity related primarily to changes in dominance (as expressed by cover) of the understorey species. The early stages of the pyric cycle were dominated by the rapid regrowth of *Pteridium esculentum* but in time its cover was reduced (Figure 5). The greater evenness of other species in the range three to ten years produced high diversity values. By 16 years the understorey was dominated by a few tall shrub species and diversity was reduced. Bell & Koch (1980) found that in jarrah forests both species richness and diversity increased to a maximum at three to five years and then declined. Russell & Parsons (1978) found in heath at Wilsons Promontory that the number of species was reduced from 60 to 49 over 21 years.

Understorey cover was not significantly correlated with either species richness or diversity. After an early increase from 40% it levels out at about 65% between five and ten years, before dropping to about 45% after 16 years. Fox & McKay (1981) have described the changes in the vertical structure of the vegetation profile for this forest for the first eight years after fire.

The relative importance of species capable of vegetative regeneration in this forest is very similar to values reported for other open-forests (Christensen *et al.* 1981). The most striking feature of the data presented here, however, is the consistency of this proportion during the 16 years since fire. This signifies that, regardless of the number of species comprising the understorey or its stage of regeneration after fire, there is the same ratio of sprouters to non-sprouters. With individuals of 47% of the species in the understorey killed by fire, a fire frequency of less than the time needed for those species to flower and set seed, could result in those species being lost from the community.

Two abutting areas of woodland in the Eurunderee embayment (just south of the Seal Rocks forest) with different recent fire histories (Fox & Fox 1986) show an interesting pattern of relative abundance of vegetative regenerators. The area that had burnt only once in the past 12 years had a ratio of 63:37 for seedling regenerators to vegetative regenerators while for the area that had burnt twice in the same period the ratio was 39:61; the area with the higher recent fire frequency had more vegetative regenerators. The Seal Rocks forest (47:53) is about half-way between these two.

Conclusions

The understorey of the open-forest at Seal Rocks rapidly regenerates following fire. Because of the abundance of species capable of regenerating vegetatively, and of obligate seedling regenerators which germinate rapidly, the species richness is quite high one month after fire and shows an interesting pattern of change with time since fire. Contrary to the decline in richness reported in the literature for other communities, the richness after 16 years is higher than that of younger sites. Cover responds quickly as well, mainly due to the rapid vegetative response of *Pteridium esculentum*. Understorey height increases linearly with time since fire.

The proportion of species capable of vegetative regrowth (53%) is similar to values reported for other open-forests. Over all sites 61% of species were resprouters and this is so for over 16 years since fire.

Acknowledgments

Some of this work was conducted while the author held a Commonwealth Postgraduate Research Award in the School of Biological Sciences, Macquarie University. The assistance of colleagues there, in particular Barry Fox, is sincerely acknowledged. Recent field work was assisted by Heidi Fallding. The comments of an anonymous referee are appreciated. The paper was revised while the author was a Visiting Scholar in the Department of Ecology and Evolutionary Biology at the University of Arizona.

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Appendix I

The vascular plant species encountered in the 60 sites. Nomenclature follows Jacobs & Pickard (1981). The mode of regeneration after fire is given (Gill 1975), and * indicates that the species is introduced.

PTERIDOPHYTES

DENNSTAEDTIACEAE
Pteridium esculentum IV
DICKSONIACEAE
Culcita dubia IV
SCHIZACEAE
Schizaea bifida V
S. dichotoma V

GYMNOSPERMS

CUPRESSACEAE
Callitris macleayana II
ZAMIACEAE
Macrozamia communis VII

ANGIOSPERMS — DICOTYLEDONS

APIACEAE
Actinotus helianthi II
Platysace ericoides II
P. lanceolata II
Trachymene incisa II
ARALIACEAE
Astrotricha longifolia II
Polyscias sambucifolia V
ASTERACEAE
**Conyza canadensis* var. *canadensis* IV
Senecio lautus III
BAUERACEAE
Bauera rubioides V
BIGNONIACEAE
Pandorea pandorana II
CAMPANULACEAE
Wahlenbergia communis II
CASUARINACEAE
Allocasuarina torulosa V
CHLOANTHACEAE
Chloanthes stoechadis II
CONVOLVULACEAE
Convolvulus erubescens II
DILLENIACEAE
Hibbertia acicularis II
H. fasciculata II
H. linearis V
H. scandens II
EPACRIDACEAE
Brachyloma daphnoides V
Leucopogon ericoides V
L. lanceolatus V
L. margarodes VI
L. virgatus V
Melichris procumbens V
Monotoca elliptica V
Styphelia viridis II
Woollsia pungens V
EUPHORBIACEAE
Breynia oblongifolia II
Poranthera micorphylla II
Ricinocarpos pinifolius V
FABACEAE — Faboideae
Aotus ericoides V
Bossiaea ensata V
B. heterophylla II
Desmodium rhytidophyllum II
Dillwynia retorta II
Gompholobium latifolium II
G. virgatum II
Hardenbergia violacea V
Hovea linearis V
Indigofera australis V
Kennedia rubicunda II
Oxylobium ilicifolium II
Phyllota phylicoides II
Platylobium formosum II
**Trifolium* sp. II

- FABACEAE — Mimosoideae
  - *Acacia falcata* II
  - *A. longifolia* II
  - *A. maidenii* II
  - *A. sophoreae* II
  - *A. suaveolens* II
  - *A. terminalis* II
  - *A. ulicifolia* II
- GOODENIACEAE
  - *Goodenia paniculata* IV
- HALORAGACEAE
  - *Gonocarpus teucrioides* II
- LAURACEAE
  - *Cassytha glabella* II
  - *Endiandra sieberi* VII
- LOGANIACEAE
  - *Mitrasacme polymorpha* II
- MYRTACEAE
  - *Angophora costata* VI
  - *Calytrix tetragona* II
  - *Eucalyptus gummifera* VI
  - *E. microcorys* VI
  - *E. pilularis* VI
  - *E. robusta* VI
  - *Leptospermum attenuatum* VI
  - *L. flavescens* V
  - *L. liversidgei* V
  - *Melaleuca quinquenervia* II
  - *M. squarrosa* II
- OLACACEAE
  - *Olax stricta* IV
- PITTOSPORACEAE
  - *Billardiera scandens* V
- PROTEACEAE
  - *Banksia integrifolia* I
  - *B. serrata* VI
  - *Conospermum taxifolium* II
  - *Persoonia lanceolata* II
  - *P. levis* VI
  - *P. linearis* VI
  - *Xylomelum pyriforme* VI
- RUBIACEAE
  - *Opercularia diphylla* II
  - *Pomax umbellata* II
- RUTACEAE
  - *Boronia pinnata* II
  - *Correa reflexa* II
  - *Eriostemon australasius* II
- SANTALACEAE
  - *Choretrum candollei* IV
  - *Leptomeria acida* IV
- SAPINDACEAE
  - *Dodonaea triquetra* II
- SMILACACEAE
  - *Smilax australis* V
  - *S. glyciphylla* V
- STERCULIACEAE
  - *Lasiopetalum ferrugineum* II
- THYMELIACEAE
  - *Pimelea linifolia* II
- TREMANDRACEAE
  - *Tetratheca thymifolia* II
- URTICACEAE
  - *Pilea microphylla* II
- VIOLACEAE
  - *Hybanthus filiformis* II
  - *Viola hederacea* II

ANGIOSPERMS — MONOCOTYLEDONS

- ANTHERICACEAE (p.p. Liliaceae)
  - *Tricoryne elatior* II
- DIANELLACEAE (p.p. Liliaceae)
  - *Dianella caerulea* IV
- CYPERACEAE
  - *Lepidosperma longitudinale* V
  - *Schoenus ericetorum* IV
- HAEMODORACEAE
  - *Haemodorum planifolium* V
- IRIDACEAE
  - *Patersonia glabrata* V
- LOMANDRACEAE
  - *Lomandra longifolia* IV
  - *L. filiformis* V
- ORCHIDACEAE
  - *Acianthus fornicatus* V
  - *Caladenia carnea* V
  - *Caleana major* V
  - *Dipodium punctatum* V
  - *Lyperanthus nigricans* V
  - *L. suaveolens* V
  - *Microtis uniflora* V
  - *Pterostylis acuminata* V
  - *Thelymitra nuda* V
- RESTIONACEAE
  - *Restio tetraphyllus* IV
- POACEAE
  - *Imperata cylindrica* IV
  - *Themeda australis* IV
- XANTHORRHOEACEAE
  - *Xanthorrhoea australis* VII

The botany of old cemeteries

E. J. McBarron, D. H. Benson and M. D. Doherty

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Abstract

McBarron[1], E. J., Benson[2], D. H., and Doherty[3], M. D. ([1]125 Dumaresq Street, Campbelltown, Australia 2560; [2]National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000; [3]National Parks and Wildlife Service, P.O. Box 1967, Hurstville, Australia 2220) 1988. The botany of old cemeteries. Cunninghamia 2(1): 97–105. — The floristic composition, both native and exotic, of seventeen cemeteries in the Campbelltown area, south-west of Sydney, was examined. A total of 505 species was recorded, 193 native, 235 exotic–naturalized, 16 native–planted and 61 exotic–planted species. Some old cemeteries may be worthy of protection as small reserves because of the reasonably high proportion (here 21-59%) or rarity of native species recorded in them. The data indicate the need to judge each on its merits. Herbicides and excessive cleaning-up are major threats.

Introduction

In long-established rural areas, remnant herbaceous or groundlayer vegetation (if it exists at all) is often confined to service corridors, and semi-neglected sites such as old cemeteries. In adjacent rural lands, however, most of the native groundlayer species have been destroyed by a century of intensive cultivation or grazing. Leigh, Boden & Briggs (1984) attribute the extinction of 57% of the 'now extinct' Australian species to agricultural practices.

The flora of service corridors generally has a mixture of native species and 'roadside weeds' of exotic origin. Such areas may be regularly or intermittently managed, traditionally by burning, but now increasingly by herbicide spraying.

Old cemeteries may have a more varied flora than service corridors. There may be some remnants of the original native flora mixed with cultivated plants, including those deliberately planted either for their funerary symbolism or personal associations, others that have become naturalized, and weeds. Price (1979) recorded nearly 400 species for Sydney's Rookwood Cemetery and adjacent hospital and golfcourse grounds; Betteridge (1981) listed 122 species for Gore Hill Cemetery.

There is public interest in the historical significance of old cemeteries (for example see Gilbert 1980) but their plants have been generally overlooked. Yet these may be important in terms of conservation and horticulture. Loneragan (1975) used a cemetery at Gingin near Perth to study patterns in vegetation using 40 native species. The cemetery had been regularly mown and burnt, but evidently included a valuable natural remnant in an otherwise agricultural landscape. Rookwood Cemetery contains valuable pockets of remnant native vegetation and includes populations of the rare shrub, *Acacia pubescens* (Price, 1979). Such sites may also provide refuges for dependent fauna. Key (1978) indicates two grasshopper species now largely restricted to cemeteries in the Southern Tablelands because of the changes to the original grasslands. As sources of old-fashioned cultivar material, roses in particular, cemeteries and churchyards are important to horticulturists and collectors (Nottle, 1983). Recent cleaning at Rookwood endangered a number of old roses well known to specialist groups such as the Heritage Rose Society (Stephanie Murphy pers. comm.).

Our aim was to examine the potential conservation value of a number of old cemeteries in terms of their native and horticultural floras. The cemeteries chosen are south-west of Sydney, on the Cumberland Plain.

Methods

Plant species are listed from 17 cemeteries at Appin, Campbelltown, Liverpool, Camden, Narellan and Denham Court; all sites on the low-rainfall part of the Cumberland Plain, south-west of Sydney (Figure 1). These cemeteries are all on Wianamatta Shale soils that originally carried woodland of *Eucalyptus moluccana*, *E. tereticornis* and *E. crebra* with a grassy, predominantly *Themeda australis*, understorey. All the cemeteries are more than 60 years old, most over 120 years old and include some of the oldest in Australia (Table 1). Cemeteries chosen all had some native species, those with only mown grass were not included.

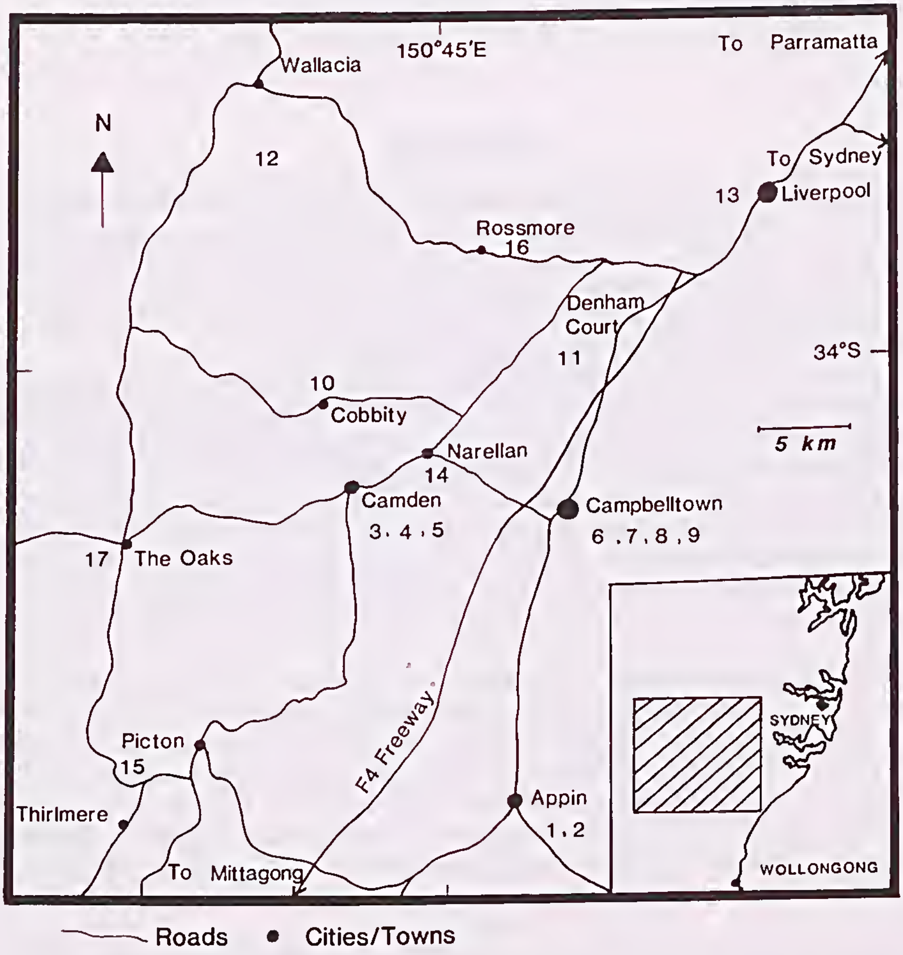

Figure 1. Location of cemeteries to the south-west of Sydney. Code numbers refer to Table 1.

Table 1: Code number, location, area and age of the 17 cemeteries examined

No.	Location	Approx. area (ha)	Oldest grave (year)
1.	Appin, St. Mark's Anglican Church	0.8	1842
2.	Appin, St. Bede's Roman Catholic Cemetery	0.6	1842
3.	Camden, General Cemetery	0.6	1924
4.	Camden, St. John's Anglican Church	1.6	1845
5.	Camden, St. Paul's Roman Catholic Cemetery, Cawdor Rd.	0.6	1843
6.	Campbelltown, Anglican Church of St. Peter	1.6	1823
7.	Campbelltown, St. John's Roman Catholic Cemetery	1.6	1827
8.	Campbelltown, Presbyterian Cemetery*	0.8	1848
9.	Campbelltown, Methodist Congregational Cemetery*	0.4	1865
10.	Cobbity, St. Paul's Anglican Church	0.8	1831
11.	Denham Court, Anglican Church of the Virgin Mary	1.2	1847
12.	Greendale, Old Roman Catholic Cemetery	0.6	1844
13.	Liverpool, General Cemetery†	2.0	—
14.	Narellan, St. Thomas' Anglican Church	0.8	1860
15.	Picton, General Cemetery	1.6	1840
16.	Rossmore, Anglican Church of the Holy Innocents	0.4	1846
17.	The Oaks, St. Matthew's Anglican Cemetery	0.6	1852

* Signifies a closed cemetery.

† Including that part of the old cemetery which was converted into the Pioneers Memorial Park in 1970–1974.

All species within the cemetery grounds were recorded, whether growing along paths, on graves, or in remnant natural vegetation. Cemetery bondaries were generally indicated by fences or clearly separated from other areas by mown lawns. Recordings were made in March, April and October 1984. Plant identifications were made by one of us (E.J.M.) and confirmed, where necessary, at the National Herbarium of New South Wales. Notes were made on the size, condition and management of the cemeteries.

Species were regarded as either native or exotic–naturalized if listed for the Central Coast Botanical Subdivision by Jacobs & Pickard (1981). Species not listed were regarded as planted, either as native–planted or exotic–planted. Five life-form classes: ferns, grasses, herbs and subshrubs, climbers and creepers, and shrubs and trees were used. The full species list is available form the Royal Botanic Gardens on request.

Results

The survey showed a rich flora with 505 species (Table 2). The number of species per cemetery ranged from 51 at Greendale (cemetery no. 12) to 164 at Liverpool (no. 13), with an average of 100 species per cemetery (Table 3).

Although only one species, the exotic herb *Plantago lanceolata* was recorded in all 17 cemeteries, 45 species were recorded from at least 50% of the cemeteries (9 or more) including 16 species from at least 75% of them (13 or more). The most frequent species were grasses and herbs.

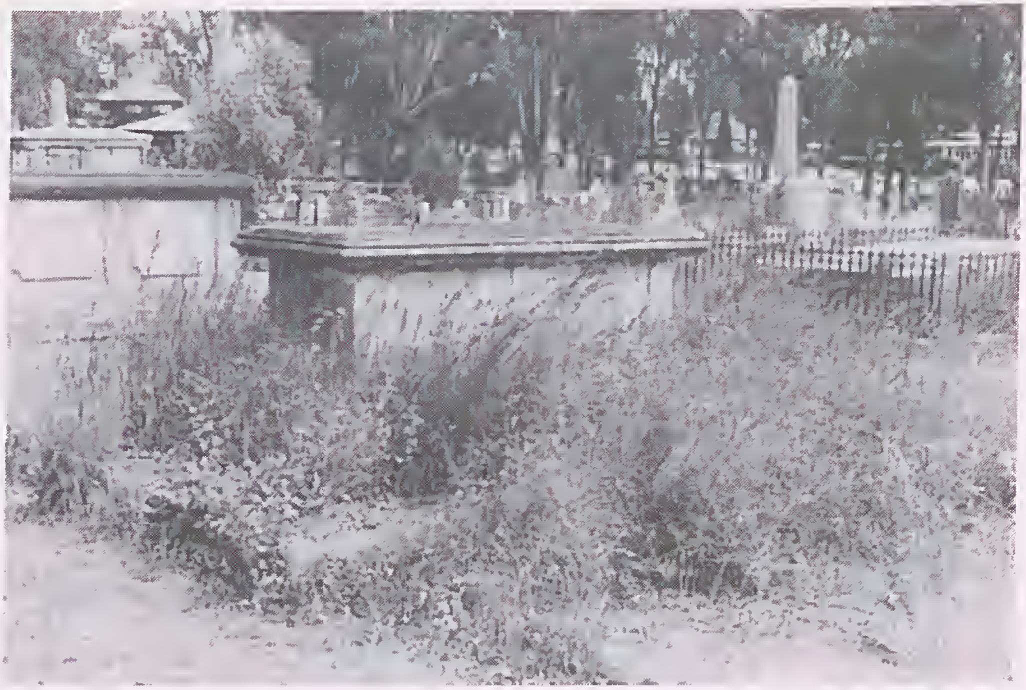

Figure 2. Grave with native *Themeda australis* and mixture of other species (Campbelltown — St Peter's Cemetery).

a) Native species

Of the flora, 193 (38%) were native species (Table 2). Of these 48% were herbs and subshrubs, 25% grasses and 20% shrubs. The number of native species per cemetery (Table 3) ranged from 17 at Cobbity Cemetery (no. 10) to 91 species at Liverpool (no. 13) (mean = 43, SD = 19). The native component made up between 21 and 59% of individual cemeteries (Table 3). The main native life-forms are herbs and subshrubs, from 8–47 species per cemetery, followed by grasses, 6–25 species per cemetery. Least important are ferns, 0–2 species per cemetery. The number of native species was not related to the size of the cemetery.

Native species either occurred in small bush remnants in undeveloped or little used parts of the cemetery, or along paths and on grave plots. Even when cemetery paths were mown, plants managed to survive in microhabitats such as the cracks in grave slabs, spaces between adjacent graves, along grave surrounds and edges, on fenced-off graves (often protected by iron surrounds), in the shade of headstones and under and around perimeter fences.

Liverpool (no. 13), with 91 native species (55% of the recorded species) had the most native species. It is largest in area and has had a fairly low intensity of usage and maintenance. Most of the native species are associated with old paths and fencelines as there are no distinct remnants of natural vegetation.

The lowest number of native species occurred in Cobbity Cemetery (no. 10), where only 17 species (22% of the recorded species) were native. This cemetery is carefully maintained, has no uncleared native vegetation and a high percentage of exotic-planted species. Most of the native species at Cobbity were growing on the grave plots themselves, rather than in untended parts of the cemetery.

Even in cemeteries with a low total number of species, native species may still comprise a very significant percentage. Greendale Cemetery (no. 12) had the

Table 2: Total numbers of species recorded by life-form and origin.

Origin	Life-form A	B	C	D	E	Total	Percentage
Native	4	49	92	9	39	193	38
Native-planted	0	0	1	0	15	16	3
Exotic	0	44	142	17	32	235	47
Exotic-planted	0	0	19	0	42	61	12
Total	4	93	254	26	128	505	
Percentage	1	18	50	5	26		100

(Life-forms: A = ferns, B = grasses, C = herbs and subshrubs, D = climbers and creepers, E= shrubs and trees.)

Table 3: Number and percentage of species recorded for the 17 cemeteries.

Cemetery	Native N %	Native-planted N %	Exotic-naturalized N %	Exotic-planted N %	Total
1.	41 (48)	0 (0)	39 (45)	6 (7)	86
2.	33 (50)	0 (0)	26 (39)	7 (11)	66
3.	35 (31)	3 (3)	69 (61)	7 (6)	114
4.	41 (30)	5 (4)	78 (57)	12 (9)	136
5.	30 (37)	0 (0)	50 (61)	2 (2)	82
6.	54 (36)	2 (2)	77 (52)	15 (10)	148
7.	48 (41)	4 (5)	57 (48)	9 (8)	118
8.	31 (31)	1 (2)	59 (59)	8 (8)	99
9.	24 (33)	0 (0)	41 (57)	7 (10)	72
10.	17 (21)	4 (5)	44 (55)	14 (19)	79
11.	45 (49)	1 (2)	39 (43)	6 (7)	91
12.	30 (59)	0 (0)	21 (41)	0 (0)	51
13.	91 (55)	3 (2)	64 (39)	6 (4)	164
14.	69 (55)	1 (1)	48 (39)	6 (5)	124
15.	33 (41)	1 (2)	40 (49)	7 (9)	81
16.	67 (49)	0 (0)	59 (43)	10 (8)	136
17.	34 (58)	6 (10)	16 (27)	3 (5)	59
Mean	43	2	49	7	100
SD	19	2	18	4	33

Cemeteries numbered as in Table 1.

lowest number of species (51) of any of the cemeteries, yet native species comprised 59% of these. This cemetery is unused and unmanaged.

Infrequent species and in particular those confined to one site made up about one-third of the native species and a similar proportion of the exotics (Table 4). Of the 74 native species found at only one site, 43% were found at Liverpool (no. 13) and 18% at Appin (no. 1). All except four cemeteries contained at least one infrequent native species.

Two native species coded as rare by Leigh, Briggs & Hartley (1981) were recorded. *Pimelea spicata*, coded 3RC (a rare species with a geographic range over 100km but not currently considered endangered or vulnerable), was found in a corner of the Narellan Cemetery. This is one of only three known surviving populations of this endemic Sydney species and a recoding of 3E (an endangered species with a range over 100km in serious risk of disappearing from the wild state within one or two decades if present land use and other causal factors continue to operate) has been recommended. *Acacia pubescens*, coded as 2E (an endangered species with a maximum geographic range of less than 100km), occurs as an uncommon plant at Liverpool Cemetery. The distribution of this species is similarly reduced. Leigh, Boden & Briggs (1984) state that land clearance for urban development poses a major threat to its continued survival in the wild. Another rare species, *Swainsona monticola*, was previously collected in St Paul's Roman Catholic Cemetery, Cawdor Rd, Camden (no. 5) by one of us (E.J.M.) in October 1965. The plants were destroyed during subsequent 'cleaning-up' and were absent in 1984. As this was the only known site in the Sydney area, the species is now locally extinct.

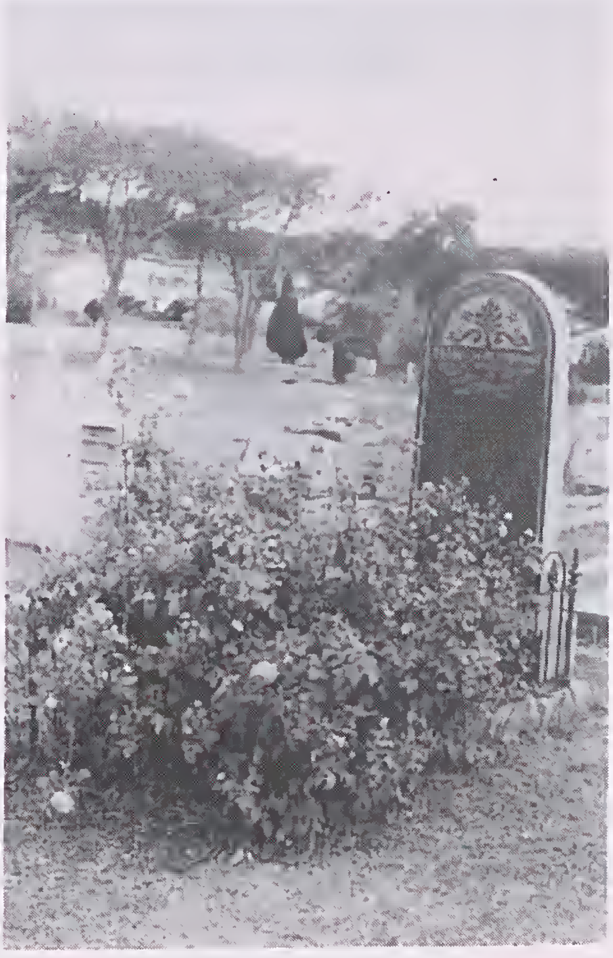

Figure 3. Grave with old rose cultivar (Picton General Cemetery).

b) Exotic–naturalized species

There were 235 exotic–naturalized species making up 47% of the total flora (Table 2). The mean number of exotic–naturalized species per cemetery ranged from 16 to 78 (mean = 49, SD = 18) (Table 3) which made up between 27% and 61% of the total number of species occurring in individual cemeteries. The main components of the exotic flora are herbs and sub-shrubs (C), 5–55 species per cemetery, followed by grasses (B), 7–21 species per cemetery. Exotic–naturalized species occupied similar microhabitats to native species.

Infrequent species, and in particular those confined to one site, made up about one-third of the exotics (Table 4). Infrequent exotic–naturalized species were found in all cemeteries (ranging from 1–12 per cemetery), but were much more evenly spread than native species.

Uncommon exotic species include *Oxalis bifurca* for which St Peter's Campbelltown (no. 6), is the only known locality in the Sydney Region (Beadle, Evans & Carolin, 1982). Species also occur which are naturalized locally but are not included in Beadle *et al.*, (1982), for example *Ornithogalum caudatum* at Rossmore (no. 16).

Table 4: Number of infrequent species* recorded for the 17 cemeteries.

Cemetery	Native	Exotic–naturalized	Native–planted and exotic–planted
1.	13	4	3
2.	6	5	3
3.	2	7	3
4.	2	10	4
5.	1	4	1
6.	1	8	4
7.	1	5	0
8.	0	2	2
9.	1	1	1
10.	1	8	5
11.	0	4	0
12.	0	3	0
13.	32	12	5
14.	9	5	1
15.	0	3	1
16.	2	5	3
17.	3	2	3

* Recorded at only one site.
Cemeteries numbered as in Table 1.

c) Native–planted

These are Australian native species that are not naturally found in the Campbelltown area. Only 16 native–planted species were recorded, 3% of the total species, and almost all were trees and shrubs. They were recorded at 11 of the 17 cemeteries. Tree species are mainly *Eucalyptus* and the shrubs mainly contemporary horticultural species. Two native species used in older plantings are *Araucaria bidwillii* and *Grevillea robusta*.

d) Exotic–planted

The exotic-planted species totalled 61 or 12% of the flora (Table 2). Two-thirds were trees and shrubs. They were found in almost all cemeteries (ranging from 0–15 species per cemetery) (Table 3). These include a number of exotic species, varieties and cultivars surviving from the Victorian era. Some were planted for their traditional associations, for example the Funereal Cypress, *Cupressus funebris* (Betteridge 1981). Other funereal plants recorded were *Pinus pinea* and the native *Araucaria bidwillii*.

The Victorian garden plants include a number of old rose species (*Rosa odorata, R. chinensis* var. *minima*) and unidentified cultivars. Some of the Victorian garden plantings reflect times before the potential for some of these hardy plants to become weeds elsewhere, particularly in bushland, was foreseen. *Oxalis* spp., *Vinca major* (Periwinkle) and *Lonicera japonica* (Honeysuckle), for instance, are now usually regarded as weeds.

Discussion

There is considerable conservation value in preserving different genotypes or variants of native species in areas where all other natural populations have disappeared, or are likely to be destroyed in the future. The network of small natural areas fulfils this role (National Trust of Australia–NSW 1984). Although not normally considered part of this network, old cemeteries may be important.

The evidence supports the case for considering some old cemeteries as having potential botanical and horticultural, as well as the normally accepted historical, conservation value. Old cemeteries may contain a surprising number of both native and exotic species, including a high proportion of 'infrequent' species. The latter include rare or locally restricted native species. Some cemeteries have higher proportions of infrequent species than others, but some may be found even in relatively tidy cemeteries. This study does not attempt to justify blanket protection of all old cemeteries, but contains data suggesting that each should be judged on its merits after survey.

The long-term conservation value (speaking in terms of centuries) of such areas is impossible to evaluate, although the older cemeteries have evidently maintained populations of species successfully for over a century. The loss of *Swainsona monticola* from one cemetery however, indicates their vulnerability to unsympathetic management. In particular herbicide spraying and excessive neatness should be avoided (see Appendix). Regrettably since the survey was completed several of the cemeteries have been sprayed or completely cleared.

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Appendix

Some recommended management procedures that will help maintain maximum species richness, particularly of native species, in a cemetery:

a) remnant stands of native vegetation should be retained
b) blanket use of herbicides should be avoided
c) the judicious use of fire is preferable to the use of chemical sprays
d) hand weeding and stump poisoning should be used to eradicate woody weeds such as lantana and privet
e) mowing should be confined to walkways and access areas
f) where native plants are a component of grassy areas, mowing should not take place until late spring (late November) in order to allow native lillies, grasses and terrestrial orchids to flower and set seed
g) mower blades should be raised a few centimetres off the ground so that the area is not cut back to bare earth
h) as there is often a concentration of native species along fencelines, a 1–2 metre wide uncleared strip should be left around fencelines where possible
i) grave plots should be left as undisturbed as possible
j) if disturbance to an area is inevitable due to expansion of the cemetery, the possibility of transplanting young plant specimens (or older specimens if there is no young material available) to an unused part of the cemetery should be investigated, especially if rare plants are involved
k) endangered plants should be left undisturbed, except for careful weeding to minimise competition and crowding.

The natural vegetation of the Katoomba 1:100 000 map sheet

D. A. Keith and D. H. Benson

(Accepted for publication 27.8.1987)

Abstract

Keith, D. A., & Benson, D. H. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1988. The natural vegetation of the Katoomba 1:100 000 map sheet. Cunninghamia* 2(1): 107–143. — The composition and extent of the present natural vegetation in the area covered by the Katoomba 1:100 000 map sheet 8930 (lat. 33°30′ – 34°00′S, long. 150°00′ – 150°30′E) is described and mapped from aerial photography and field traverses. The structure, characteristic species and associated environmental factors for 32 map units with 45 plant communities are described. These include small areas of rainforest and eucalypt tall open-forest, extensive tracts of open-forest and woodland, and patches of sclerophyllous heath and sedge-swamp.

Vegetation patterns are influenced by geology (mainly sedimentary and metasedimentary with limited igneous rocks), soil types (mainly low nutrient acid soils with variable texture), physiography (dissected sandstone plateaux and deep gorges), and by trends in elevation (ranging from 100 m to 1360 m above sea level) and rainfall (ranging from 750 mm to 1450 mm per annum).

Significant plant communities and rare species are listed. Plant communities needing conservation protection occur particularly in the Coxs River valley while rare localized species are concentrated in the wet habitats of the Upper Blue Mountains. Future management problems will relate to stream pollution and exotic weed invasion from increasing urban runoff, and changes in fire regimes near urban areas. There is a need for further botanical research into these problems.

Introduction

> 'Lofty, densely-timbered, mountainous ranges now appeared before us, peering over each other ... their peculiar faces overhanging deep ravines as to seem to defy all further attempt to penetrate westerly.' Allan Cunningham (King's Botanist) 27th November 1823, quoted in Lee (1925).

Allan Cunningham's romantic vision from the slopes of Mt Tomah epitomises the outstanding elements of the Blue Mountains landscape: grand scenery and inaccessibility. His reference to 'lofty, densely-timbered, mountainous ranges', probably relating to forests on the basalt-capped peaks of the northern Blue Mountains, contrasts starkly with a later description of nearby sandstone vegetation — 'scanty and miserably stunted and gnarled timber' (Eccleston du Faur 1879). Such remarkable contrasts in vegetation occur within the area covered by the Katoomba 1:100 000 sheet.

The Katoomba 1:100 000 Vegetation Sheet (based on Katoomba 1:100 000 Topographic Sheet 8930, Division of National Mapping) is bounded by latitudes

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* Present address: National Parks and Wildlife Service, P.O. Box 1967, Hurstville, Australia 2220.

33°30′ – 34°00′S and longitudes 150°00′ – 150°30′E. It covers the Upper Blue Mountains, from Mt Wilson south to Lake Burragorang and the Coxs River, and west from Woodford to the Great Dividing Range. Elevation ranges from 100 to 1360 metres above sea level. This is the second sheet to be published in the Sydney Region Vegetation Map Series (See Figure 1).

Native vegetation in Blue Mountains National Park and Warragamba Catchment Area covers most of the map sheet. The main population centres are the chain of Blue Mountains towns along the Western Railway Line and Great Western Highway, including Woodford, Lawson, Wentwoth Falls, Leura, Katoomba, Blackheath and Mt Victoria. There are small rural settlements in the Coxs River valley.

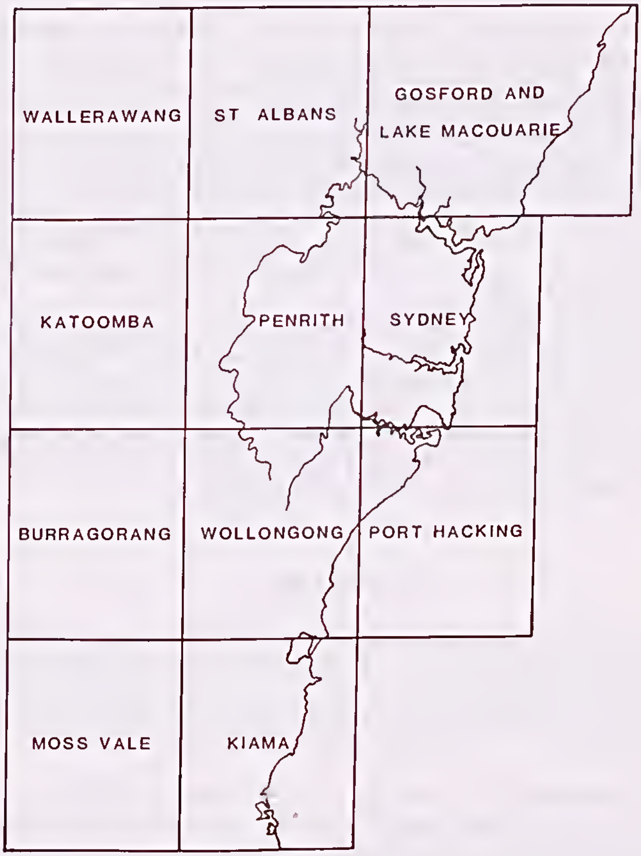

Figure 1. Key map for the 1:100 000 sheets in the Sydney Region Vegetation Map Series.

Climate

Average maximum temperatures relate strongly to altitude (Bureau of Meteorology 1979). Average January maxima are highest (28°C) around Lake Burragorang (150 m), decreasing to 23°C at Mt Victoria (1050 m) and 22°C at Jenolan State Forest (1150 m). Average minimum temperatures generally decrease from east to west. Average July minima range from 2 to 3°C at Wentworth Falls (900 m) to 0°C at Jenolan State Forest (1150 m). Temperatures as low as −3°C and −11°C have been recorded for Katoomba and Jenolan Caves respectively.

Winds from the west or northwest predominate all year round, though there are significant easterly and northeasterly winds during the summer months, November to April (data from Mt Victoria, Bureau of Meteorology 1979).

Rainfall patterns relate to elevation and distance from the coast (Bureau of Meteorology 1979). Average annual rainfall increases from 1100 mm near Woodford to 1400 mm at Leura and 1450 mm at Mt Tomah. There is a rainshadow effect in the Coxs River Valley, Little Hartley and Bowenfels receiving 750 mm and 780 mm respectively. Further west, at higher elevation, Jenolan State Forest receives 1150 mm annually. The driest months are generally July to September and the wettest are December to March, although the drier areas show little seasonality (Table 1).

Fogs occur frequently on the higher Blue Mountains, with Katoomba and Mt Victoria recording 55 and 90 fog days per year respectively. Frosts occur on 35 to 40 days of the year, mostly between April and November, half of these are regarded as 'severe' (Bureau of Meteorology 1979). Snow falls most frequently in July and August, Katoomba and Mt Victoria have an average of 3 and 10 snow days respectively per year.

Table 1: Average monthly rainfall (mm).

Station (altitude)	J	F	M	A	M	J	J	A	S	O	N	D	Total
Leura P.O. (975 m)	158	177	146	131	106	132	87	75	74	93	100	125	1401
Little Hartley (810 m)	79	73	69	59	55	66	62	53	45	55	59	73	748
Jenolan S.F. (1158 m)	113	115	99	81	86	117	80	93	71	96	93	105	1149

Geology and geomorphology

> 'These walls or cliffs rise . . . perpendicularly above the road, and their summits, broken and fissured in various fantastic forms, exactly resemble a ruined castle crowning the brow of the sheer precipice, with here and there a stunted tree or graceful shrub growing from crevices in the dark rock.' Louisa Ann Meredith at Hassans Walls (Meredith 1844).

The map sheet area lies on the western edge of the Sydney Basin. The Great Dividing Range traverses its northwestern edge and almost all of the area drains into the Hawkesbury–Nepean River System. Major watercourses include: Coxs River, flowing south then east into Lake Burragorang; Jenolan, Kanangra and Kowmung Rivers which drain the southwestern part of the area and join the Cox; the Kedumba River, flowing south into Lake Burragorang; and the Grose River which drains most of the Blue Mountains plateau and flows east to join the Nepean River. The highest parts of the area are in the southwest, with Mt Bindo (west of Hampton) reaching 1363 m and Ben Lomond (on the Boyd Plateau) reaching 1330 m.

The Blue Mountains, an extensive, dissected Triassic sandstone plateau, dominate the eastern half of the map sheet area. They rise from 500 to 600 m on the eastern edge of the map area to 1100 m near Mt Victoria, terminating in a spectacular north–south line of cliffs along the eastern side of the Hartley, Kanimbla and Megalong Valleys (Bembrick 1980). Hawkesbury Sandstone covers the eastern margin of the map area, with residual Wianamatta Shale capping the Bilpin Ridge and outcropping on Mt Tomah. Strata of the Narrabeen Group make up the main plateau. These consist of massive sandstone strata interbedded with narrow claystone bands, outcrops of which are associated with the formation of swamps in headwater valleys (Holland 1972).

Major peaks in the Blue Mountains, including Mt Wilson, Mt Haystack, Mt Tomah, Mt Bell, Mt Banks, Mt Caley and Mt Hay, are capped by remnants of Tertiary basalt. In a few places, most notably at Murphys Glen, diatremes or volcanic necks have intruded through the sandstone, though these are more common to the north and east of the map sheet area (Crawford *et al.* 1980).

At the base of the Triassic sandstone escarpment the Permian Illawarra Coal Measures are exposed. These incude shales, sandstones, conglomerates and chert with coal and torbanite seams (New South Wales Department of Mines 1966). The rapid weathering of these softer rocks undercuts the more resistant Triassic sandstones which collapse along joint lines to leave spectacular cliffs. While the Illawarra Coal Measures are mostly restricted to a narrow band below the clifflines, the Permian Shoalhaven Group, which underlies the coal measures, outcrops over larger areas beyond the escarpment as well as a number of residual cappings in the west of the area. Shoalhaven Group rocks include shales, conglomerates and sandstones. Both Permian rock types are exposed in the deeply entrenched Grose River gorge.

There is a large Carboniferous igneous intrusion, the Kanimbla Batholith, on much of the northwestern part of the map area, including the upper Coxs River valley and three outliers in the southwest. Uniform weathering of the adamellites, granites and granodiorites of this unit has given rise to the characteristically undulating 'granite country'. Smaller intrusions of gabbro and diorite are found in the western part of the map area (New South Wales Department of Mines 1966).

The Devonian Lambie Group underlies the Permian sediments, occupying a large area in the southwest of the map area. Smaller outcrops are exposed west of Lithgow, south of Hartley and in the Kedumba Valley. The quartzites, sandstones, siltstones and claystones of this group have been sculptured into very rugged country with mazes of deep gorges, steep slopes and narrow ridges. The Kanangra Gorge, for example, is up to 500 m deep.

The oldest rocks in the area are Devonian rhyolites and rhyo-dacites and Silurian tuff, limestones, siltstones, phyllites and slates which both outcrop in the Boyd Plateau–Jenolan Caves area (New South Wales Department of Mines 1966).

Soils

Soil types in the area covered by the Katoomba map sheet are described by Hamilton (1976). Soils derived from Triassic Sandstones in areas of high relief are grey-brown and yellow-brown uniform sands. Sandy yellow leached gradational soils (with ironstone gravel) are found on flatter parts of the plateau, paticularly from Katoomba to Mt Victoria. These 'sandstone soils' are rapidly permeable, very acid and very infertile.

Hardsetting loamy red and yellow texture-contrast soils (with ironstone gravel) are found on remnants of Wianamatta Shale on the Bilpin Ridge. These are moderately to slowly permeable, very acid and relatively infertile. Small areas of Tertiary basalt on the plateau have given rise to brown and red friable clay loams with moderate to slow permeability, slightly acid to neutral with high fertility.

Hardsetting yellow texture-contrast sandy loams occur on the Permian sandstone, shale and conglomerate deposits. These are moderately to slowly permeable, acid and relatively infertile.

Red-brown gradational sandy loams in the Coxs River valley are derived from Carboniferous granites. These soils are deep, rapidly permeable in their upper horizons, acid and have low to moderate fertility.

On the Devonian and Silurian substrates in the southwest of the map area are yellow leached gradational loams with moderate to slow permeability, acid with low fertility.

Land Use

Aborigines first occupied the Blue Mountains at least 14 000 years ago, and at various times three tribes may have used the area: the Gangangara people from the south; the Wiradjuri from the west; and the Daruks from the east (Robertson 1985).

Today much of the country still has natural vegetation and is protected within Blue Mountains National Park which covers most of the eastern half of the map area. Additional natural areas are found in Kanangra-Boyd National Park and Warragamba Catchment Area in the south, most of which is managed jointly by the National Parks and Wildlife Service and the Metropolitan Water, Sewerage and Drainage Board. A ribbon of tourist resorts and residential development has grown along the Main Western Railway.

Early European travellers found 'a wild and barren country' (Louisa Ann Meredith) though 'quite novel and extremely magnificent' (Charles Darwin). Less flattering was Barron Field, who at Blackheath saw hills, 'thrown together in a monotonous manner, and their clothing is very unpicturesque — a mere sea of harsh trees' (all quoted in Mackaness 1980). The spectacular landscapes of the Blue Mountains have inspired tourists from the mid-nineteenth century until the present.

There has been grazing in the Coxs River valley since the first road across the Blue Mountains was constructed in 1815. Orchards are a minor agricultural use on the Bilpin Ridge and Shipley Plateau.

Major forestry operations are associated with extensive pine plantations in Hampton and Jenolan State Forests. Native forests here, and on the Boyd Plateau (formerly Konangaroo State Forest), have been heavily logged, mainly for *Eucalyptus fastigata*.

Underground mining of the Illawarra Coal Measures is a major industry in the Bell–Lithgow area and there are small abandoned mines where the coal seams outcrop below the excarpment as far south as Mt Solitary. There are also major sand extraction sites on the plateau at Clarence.

The vegetation

(i) Methods

The vegetation has been classified into structural forms using the system proposed by Specht (1970). The structural forms are further subdivided into plant communities characterized by the dominant species. An alphanumeric code is used to identify individual map units. The numeric code represents the structural form of the plant community as determined from Specht (1970); (see Benson 1986) and the alphabetic code represents the characteristic species. The codes used are consistent throughout the Sydney region 1:100 000 vegetation map series, allowing the communities to be cross-referenced between maps. This system has been used in Queensland for the Moreton Region Vegetation Map Series (e.g. McDonald & Whiteman 1979).

Areas of vegetation with similar structural and floristic characteristics were grouped on the basis of aerial photopatterns, current geological mapping and limited field checking to form the map units. Black and white 1979/80 aerial photography by the New South Wales Department of Lands (approx. scale 1:40 000) was used. Only present day (that is, 1979/80) natural vegetation is mapped, though comments on the original vegetation of some cleared areas are provided. Compilation maps were prepared at 1:25 000 scale and subsequently reduced to 1:100 000 scale. Dyeline copies of the 1:25 000 compilation map sheets (Hartley, Mt Wilson, Hampton, Katoomba, Jenolan, Jamison, Kanangra and Bimlow) are available on request from the Royal Botanic Gardens, Sydney.

There are a number of constraints in reducing the complex pattern of natural vegetation to a map format. The map units recognized are not all of equivalent rank. This is because a number of them are essentially land units made up of several plant communities associated with a particular geological or physiographic type (e.g. map unit 10a), whereas others are more clearly plant associations (*sensu* Beadle & Costin 1952; e.g. map unit 26a). Generally the term 'plant community' is used for the basic vegetation unit. Where vegetation boundaries are relatively distinct, they are mapped with an unbroken line and where more diffuse, with a broken line. Communities have also been provided with common names based loosely on habitat and composition, for ease of reference.

Fieldwork was mostly conducted during the period 1983 to 1985. The descriptions of map units include notes on habitat, vegetation structure and the characteristic species of major strata. Reference has been made to any available descriptions or species lists.

Botanical names are those currently recognized at the National Herbarium of New South Wales. Recent nomenclatural changes include a revision of *Banksia* (George 1981), *Tristania* and allied genera (Wilson & Waterhouse 1982) and the separation of *Allocasuarina* from *Casuarina* (Johnson 1982).

General descriptions of the vegetation of Triassic sandstone areas were included in Pidgeon's (1937, 1938, 1940, 1941) vegetation study of the Central Coast of New South Wales. A broader view of vegetation patterns can be obtained from Beadle (1981). There have also been short studies done for environmental impact assessment work or university studies, copies of which are often very difficult to obtain. Dyson (1969), for example, surveyed the forests of the inner Warragamba Catchment, Black (1976, 1982) described and mapped the vegetation of the Boyd Plateau, while Duncan (1974) studied the vegetation of Kanangra Walls and Ti-Willa Plateau. An extensive species list for the map sheet area is being compiled by the National Herbarium and is available on request (for other lists see Pickard 1972, Bryant & Benson 1981 and Keith 1988). More generalized accounts of the vegetation of the Blue Mountains include those of Armstrong (1981) and Morrison (1985).

A summary of the plant communities recognized here, their structural formation, main canopy species, altitudinal range and geological substrate are given in Table 2. The vegetation map sheet is located inside the back cover.

(ii) Descriptions of map units

The map unit numbering system applies to the complete vegetation map series. Missing numbers are those used for plant communities that are not found on the Katoomba sheet.

Map unit 6c 'Glen Forest'.

Tall open-forest: *Eucalyptus deanei–Syncarpia glomulifera*.

In the lower Blue Mountains there are a number of diatremes, small amphitheatre-shaped valleys formed from eroded volcanic necks of Jurassic age, described in detail by Carne (1908). Murphys Glen is the best example on the Katoomba 1:100 000 map sheet, though others occur on Kings and Bimlow Tablelands. The soils in diatremes are deep, moist, sandy loams, derived from the mixing of sandstone and basalt or breccia substrates. This results from ring-faulting and collapse of the sandstone wall-rocks into the volcanic intrusion and the subsequent deposition of sand eroded from the surrounding sandstone ridges (Crawford *et al.* 1980).

The vegetation is tall open-forest dominated by trees of *E. deanei* and *Syncarpia glomulifera* with some *Angophora costata* ssp. *costata*. The understorey has tall shrubs of *Notelaea longifolia, Acacia obtusifolia, Pultenaea flexilis, Hakea dactyloides* and *Polyscias sambucifolia*. Climbers and scramblers are common including *Smilax australis, Tylophora barbata, Eustrephus latifolius, Cissus hypoglauca, Hibbertia dentata, Clematis aristata* and *Comesperma volubile*. The ground cover is dominated by *Culcita dubia, Dianella caerulea, Lomandra longifolia* and *Pteridium esculentum*.

Map unit 6d 'Camden White Gum Forest'.

Tall open-forest: *Eucalyptus benthamii– E. deanei*.

This community is restricted to the sandy loams of the narrow alluvial plain of the lower Kedumba River. *Eucalyptus benthamii* and *E. deanei* are dominant with the occasional *Angophora floribunda*. The understorey includes large shrubs of *Acacia parramattensis, A. filicifolia* and *Leptospermum flavescens* with a ground cover of *Imperata cylindrica*. Smaller, unmapped areas of Community 6d include a regenerating stand on cleared land at Reedy Creek and a small stand at Hayes Crossing on Cedar Creek. Other stands along the lower Coxs River were inundated following the construction of Warragamba Dam.

Eucalyptus benthamii was also originally found along the Nepean River, but with much of the Nepean Plain now cleared for agriculture, the *E. benthamii* community is known there only from Bents Basin near Wallacia where it occurs with *E. elata* (Benson 1985). A scattering of trees persists along the banks of the Nepean River between Wallacia and Camden.

Map unit 6g 'Moist Basalt Cap Forest'.

Tall open-forest: *Eucalyptus viminalis–E. blaxlandii–E. fastigata*.

> 'Upon entering the forest, the traveller is struck with the change in the appearance of the timbers from the Eucalypti [*sic*] of the open country, the stupendous size and extra-ordinary windings of the climbers . . . and with the magnificence of the tree ferns.' Allan Cunningham quoted in Lee (1925).

The Tertiary basalt caps of Mt Wilson, Mt Tomah, Mt Bell, Mt Banks, Mt Caley and Mt Hay in the Blue Mountains weather to a fertile clay-loam soil. At elevations of 800 to 1000 m this supports a tall open-forest on the summits and slopes, and rainforest (map unit 8c) in the moist, sheltered gullies, particularly those associated with the larger basalt areas of Mt Wilson and Mt Tomah.

In the tall open-forest on Mt Wilson *E. viminalis* and *E. blaxlandii* predominate with some *E. cypellocarpa*. On the other smaller peaks *E. viminalis* is replaced by *E. fastigata*, while *E. oreades* frequently inhabits more rocky slopes on the edges of the basalt.

Table 2: Map unit, common name, structure, main canopy species, geology and habitat of plant communities in the area covered by the Katoomba 1:100 000 map sheet.

Map unit	Structure	Main canopy species	Geology	Altitude	Habitat
6c	'Glen Forest'				
	TALL OPEN-FOREST	*Eucalyptus deanei* *Syncarpia glomulifera*	Jurassic diatremes	<650 m	Amphitheatre-shaped gullies
6d	'Camden White Gum Forest'				
	TALL OPEN-FOREST	*E. benthamii* *E. deanei*	Recent alluvium	<150 m	Banks of Kedumba River
6g	'Moist Basalt Cap Forest'				
	TALL OPEN-FOREST	*E. viminalis* *E. blaxlandii* *E. fastigata*	Basalt caps	>800 m	Ridges and slopes of residual basalt
6h	'Escarpment Complex'				
	TALL OPEN-FOREST	*E. deanei* *E. cypellocarpa* *Syncarpia glomulifera*	Illawarra Coal Measures	120–850 m	Escarpment slopes
	OPEN-FOREST	*Angophora costata* *E. piperita* *E. punctata*	Shoalhaven Group	120–850 m	Undulating country below escarpment slopes
	CLOSED-FOREST	*Ceratopetalum apetalum* *Doryphora sassafras*	Illawarra Coal Measures	120–850 m	Sheltered gullies on escarpment slopes
8c	'Montane Rainforest'				
	CLOSED-FOREST	*Ceratopetalum apetalum* *Doryphora sassafras* *Quintinia sieberi*	Illawarra Coal Measures, Tertiary basalt	600–1000 m	Sheltered gullies on escarpment slopes. Also found on basalt caps
8d	'Kowmung Dry Rainforest'				
	CLOSED-FOREST	*Toona australis* *Ehretia acuminata* *Brachychiton populneum*	Devonian Lambie Group	300–700 m	Sheltered lower slopes in deeply dissected Kowmung area
9a	'Shale Cap Forest'				
	OPEN-FOREST	*Eucalyptus notabilis* *E. globoidea* *Syncarpia glomulifera*	Wianamatta Shale	<750 m	Ridgetop, Berambing to Bilpin
9i	'Blue Mountains Sandstone Plateau Forest'				
	OPEN-FOREST	*E. sieberi* *E. piperita*	Narrabeen Group	800–1150 m	Dissected sandstone plateaux
9j	'Montane Gully Forest'				
	OPEN-FOREST	*E. fastigata* *E. cypellocarpa* *E. dalrympleana*	Narrabeen Group	850–1100 m	Gorges and sheltered escarpment slopes
9m	'Megalong Forest'				
	OPEN-FOREST	*Angophora costata* *E. punctata* *E. sieberi*	Shoalhaven Group	400–750 m	Undulating country below escarpment slopes
9n	'Montane Moist Forest'				
	OPEN-FOREST	*E. fastigata* *E. dalrympleana* *E. viminalis*	Lambie Group, Carboniferous granites	>700 m	Steep slopes and moist sheltered gullies

Map unit	Structure	Main canopy species	Geology	Altitude	Habitat
9x	'River Oak Forest'				
	OPEN-FOREST	*Casuarina cunninghamiana*	Alluvium	<800 m	Along major watercourses
10ag	'Sydney Sandstone Complex'				
	OPEN-FOREST	*Angophora costata* *E. piperita* *E. agglomerata* *Syncarpia glomulifera*	Narrabeen Group, Hawkesbury Sandstone	<800 m	Dissected plateau in gullies
10ar	'Sydney Sandstone Complex'				
	WOODLAND	*E. gummifera* *E. sclerophylla* *E. oblonga*	Narrabeen Group, Hawkesbury Sandstone	<800 m	Dissected plateau on ridges
10h	'Tablelands Grassy Woodland Complex'				
	WOODLAND	*E. dives* *E. mannifera* *E. eugenioides*	Shoalhaven Group	>800 m	Undulating to hilly country
	WOODLAND	*E. pauciflora* *E. rubida*		>800 m	Valleys with frost hollows
	WOODLAND	*E. aggregata* *E. mannifera* *E. stellulata*		>800 m	Poorly drained depressions
10l	'Snow Gum Woodland'				
	WOODLAND	*E. pauciflora* *E. dalrympleana*	Lambie Group, Carboniferous granites	>1100 m	Undulating country on Great Dividing Range
	WOODLAND	*E. pauciflora* *E. rubida* *E. stellulata*		>1100 m	Poorly drained hollows
10m	'Mount Walker Complex'				
	WOODLAND	*E. macrorhyncha* *E. melliodora*	Devonian Lambie Group	>600 m	Rugged country around Mt Walker and south of Hartley
10o	'Yellow Box Woodland'				
	WOODLAND	*E. melliodora* *E. viminalis*	Carboniferous granites	250–850 m	Coxs River Valley
10p	'Kowmung Wilderness Complex'				
	WOODLAND	*E. tereticornis* *E. melliodora*	Devonian Lambie Group	<900 m	Dissected country of the lower Cox and Kowmung Rivers. Gullies and moist slopes
	WOODLAND	*E. fibrosa* *E. crebra* *E. eugenioides* *E. punctata*	Devonian Lambie Group	<900 m	Dissected country of the lower Cox and Kowmung Rivers. Ridges and drier aspects
10q	'Burragorang Ironbark Woodland'				
	WOODLAND	*E. crebra* *E. eugenioides* *E. punctata* *E. fibrosa*	Shoalhaven Group	<500 m	Undulating country

Map unit	Structure	Main canopy species	Geology	Altitude	Habitat
	WOODLAND	*E. sclerophylla* *Angophora bakeri*	Shoalhaven Group	<500 m	Western aspect of ridges in Kedumba Valley
10r	'Residual Sandstone Woodland'				
	WOODLAND	*E. sieberi* *E. blaxlandii*	Shoalhaven Group	>900 m	Rocky, high altitude ridges
10s	'Montane Woodland'				
	WOODLAND	*E. radiata* *E. dalrympleana*	Lambie Group, Carboniferous granites, Shoalhaven Group	>900 m	Gentle slopes, ridges & undulating country
	WOODLAND	*E. ovata* *E. stellulata*			Poorly drained depressions
10t	'Mount Blaxland Complex'				
	WOODLAND	*E. sieberi* *E. pulverulenta*	Devonian metamorphic & igneous rocks	700–1000 m	Mt Blaxland, Wentworths Sugarloaf
10u	'Jenolan Granite Woodland'				
	WOODLAND	*E. punctata* *E.* sp. nov. 'MAHEK' *E. sieberi*	Carboniferous granites	300–1100 m	Steep north-facing slopes
17a	'Black Range Scrub'				
	OPEN-SCRUB	*E. mannifera* *Leptospermum myrtifolium* *L.* sp. nov. 'A' *Patersonia fragilis*	Devonian Lambie Group	1050–1150 m	Soaks on southerly aspects of Black Range
20a	'Newnes Plateau Shrub Swamps'				
	CLOSED-HEATH	*Leptospermum lanigerum* *Baeckea linifolia* *Grevillea acanthifolia* *Xyris ustulata*	Narrabeen Group	>1000 m	Shrub-swamps in narrow headwater valleys
20b	'Coxs River Swamps'				
	CLOSED-HEATH	*Leptospermum obovatum* *L. juniperinum* *Grevillea acanthifolia*	Illawarra Coal Measures	>600 m	Valleys and headwaters of creeks
21c	'Montane Heath'				
	OPEN-HEATH	*E. stricta* *Allocasuarina nana* *Leptospermum attenuatum* *Phyllota squarrosa* *Eriostemon obovalis*	Narrabeen Group	>850 m	Exposed rocky ridges on shallow sandy soils, often on western aspects
	OPEN-HEATH	*Epacris reclinata* *Dracophyllum secundum* *Gleichenia rupestris*		>850 m	Moist rock faces
21d	'Pagoda Rock Complex'				
	OPEN-HEATH	*Allocasuarina nana* *Leptospermum arachnoides* *Lepidosperma viscidum*	Narrabeen Group	>750 m	Exposed sites on rock outcrops with shallow soils. Associated with extensive rocky platforms and 'Pagoda' rock formations

Map unit	Structure	Main canopy species	Geology	Altitude	Habitat
	OPEN-SCRUB	*Eucalyptus* sp. nov. 'MOK11'		>750 m	
	WOODLAND	*E. sieberi* *E. piperita*		>750 m	Small sheltered gullies between rocky knolls
21f	'Lower Blue Mountains Heath'				
	OPEN-HEATH	*E. stricta* *Allocasuarina nana* *Leptospermum attenuatum* *Phyllota phylicoides* *Eriostemon hispidulus*	Narrabeen sandstone	<850 m	Exposed rocky ridges on shallow sandy soils, often on western aspects
	OPEN-HEATH	*Epacris reclinata* *Dracophyllum secundum* *Gleichenia rupestris*		<850 m	Moist rock faces
26a	'Blue Mountains Sedge Swamps'				
	CLOSED-SEDGELAND	*Gymnoschoenus sphaerocephalus* *Lepidosperma limicola* *Xyris ustulata* *Baeckea linifolia*	Narrabeen sandstone with peaty sand	<1000 m	In headwater gullies or on hillsides
26b	'Boyd Plateau Bogs'				
	CLOSED-SEDGELAND	*Carex appressa* *C. gaudichaudiana* *Juncus holoschoenus* *Baeckea utilis*	Carboniferous granite with acid peats	>1200 m	In headwater gullies
	CLOSED-HEATH	*Leptospermum myrtifolium* *L. obovatum* *L. lanigerum*		>1200 m	In headwater gullies
C	Cleared	Native vegetation has been largely removed for agricultural, industrial or urban development but remnant vegetation of varying sizes and condition may remain.			

The understorey generally has scattered shrubs including *Acacia melanoxylon, A. penninervis, Polyscias sambucifolia, Astrotricha floccosa, Daviesia ulicifolia* and *Leucopogon lanceolatus* var. *lanceolatus*, and occasional tree ferns, *Cyathea australis*. There is a continuous ground cover of herbs such as *Libertia paniculata, Dianella laevis, Geranium solanderi* var. *solanderi, Viola betonicifolia, Centella asiatica* and *Stellaria pungens*, with ferns including *Blechnum cartilagineum, B. nudum, Doodia aspera* and *Pteridium esculentum*.

On the Boyd Plateau at Whalania Heights and south of Cunynghame Hill, basalt outcrops at much higher elevations (above 1200 m) but supports similar tall open-forest with *E. viminalis* and *E. fastigata*. Occasional shrubs in the understorey here include *Pultenaea altissima, Acacia dealbata, A. melanoxylon* and *Rubus parvifolius*, together with herbs such as *Geranium potentilloides* var. *abditum, Epilobium billardieranum* ssp. *cinereum, Acaena novae-zelandiae* and *Luzula flaccida*, and ferns including *Polystichum proliferum* and *Blechnum nudum*.

Ingram (1972) recounts the botanical history of Mt Tomah and provides a species list, while Brough, McLuckie & Petrie (1924), Petrie (1925) and McLuckie & Petrie (1926) give detailed descriptions of the vegetation of Mt Wilson.

Map unit 6h 'Escarpment Complex'.

Tall open-forest: *Eucalyptus deanei–E. cypellocarpa–Syncarpia glomulifera.*

Open-forest: *Angophora costata* ssp. *costata–E. piperita–E. punctata.*

Closed-forest: *Ceratopetalum apetalum–Doryphora sassafras.*

This map unit is a mosaic of three communities found on the moderate to steep slopes below the Triassic sandstone escarpments at low to moderate altitudes (120 to 850 m). The soils are relatively deep, moist but well-drained sandy loams with colluvial material from shales, sandstones and conglomerates of the Permian Illawarra Coal Measures and, to a lesser extent, the Shoalhaven Group.

The most widespread community in this unit is a tall open-forest dominated by *E. deanei, Syncarpia glomulifera, Angophora costata* ssp. *costata* and *Acacia elata. Eucalyptus cypellocarpa* replaces *E. deanei* at higher altitudes (above about 650 m), particularly along the slopes around Narrow Neck Peninsula (Figure 2). *Eucalyptus oreades* may be present on the upper slopes. There is a sparse small-tree stratum of *Callicoma serratifolia, Hakea salicifolia* and *Allocasuarina littoralis.* The understorey has a dense fern cover of *Culcita dubia, Pteridium esculentum* and *Blechnum cartilagineum,* with occasional emergent shrubs of *Platylobium formosum, Oxylobium ilicifolium, Bursaria longisepala, Leucopogon lanceolatus* var. *lanceolatus and Pultenaea scabra var. scabra.* Herbs and twiners include *Dianella caerulea, Clematis aristata, Smilax glyciphylla, Lomandra longifolia, Viola hederacea, Pratia purpurascens* and *Helichrysum scorpioides.* Blue Gum Forest in the Grose Valley is a good example of this community, though here *Eucalyptus deanei* occurs as a pure stand.

On the less sheltered, undulating terrain of the Kedumba and Grose Valleys, away from the escarpment, there is an open-forest community with *Angophora costata* ssp. *costata, E. piperita* ssp. *piperita, E. punctata, E. gummifera, E. oblonga* and *E. sieberi* in various combinations. This occurs on drier, more sandy soils on the sandstones and conglomerates of the Shoalhaven Group. While larger stands are mapped separately as 'Megalong Forest', small areas of this vegetation are associated with the 'Escarpment Complex'. Floristically this resembles the 'Sydney Sandstone Complex' vegetation on the Hawkesbury Sandstone (map units 10ag/10ar). The understorey is shrubby, 1 to 2 m tall and includes a diversity of proteaceous, myrtaceous and fabaceous shrubs such as *Banksia spinulosa* var. *spinulosa, B. serrata, Lambertia formosa, Persoonia linearis, Leptospermum attenuatum, Dillwynia retorta* and *Oxylobium ilicifolium.*

In moist, sheltered gullies running down the steep escarpment slopes (for example below Little Cedar Gap and below the Horseshoe Falls at Govetts Leap), a closed-forest community dominated by rainforest species, *Ceratopetalum apetalum, Acmena smithii* and *Doryphora sassafras* occurs. These narrow bands of rainforest are usually overtopped by eucalypt emergents, *E. deanei, E. cypellocarpa* or *E. oreades.* Small trees include *Backhousia myrtifolia, Tristaniopsis collina, Callicoma serratifolia, Elaeocarpus reticulatus, Pittosporum revolutum, Eupomatia laurina, Rapanea howittiana, Hedycarya angustifolia* and *Notelaea longifolia.* The understorey consists of occasional ferns such as *Blechnum cartilagineum, B. patersonii, Polystichum proliferum, Doodia aspera* and *Cyathea australis,* with vines of *Pandorea pandorana, Morinda jasminoides, Smilax australis, Eustrephus latifolius* and *Cissus hypoglauca* also present.

Map unit 8c 'Montane Rainforest'.

Closed-forest: *Ceratopetalum apetalum– Doryphora sassafras–Quintinia sieberi.*

Larger areas of Warm Temperate rainforest are found on sheltered southerly and south-easterly aspects of Mt Wilson and Mt Tomah and in the adjacent sandstone gullies with an elevational range from 600 to 1000 m. The soils here are

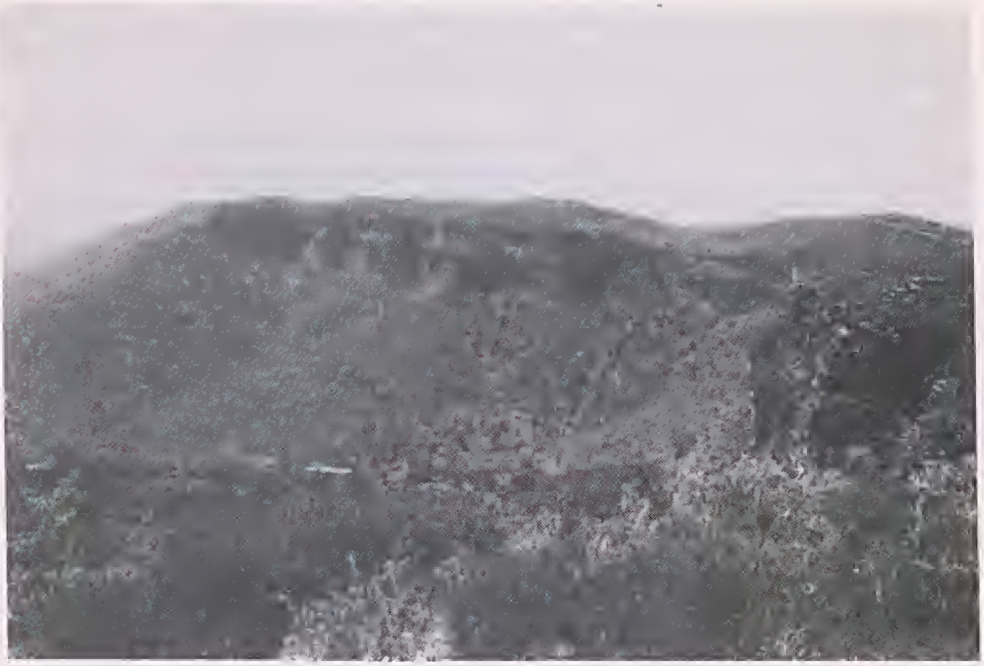

Figure 2. Looking north along the western escarpment of the Narrow Neck peninsula. Tall open-forest of *Eucalyptus cypellocarpa* dominates the slopes above Megalong Valley, with narrow bands of closed-forest in the heads of the gullies (map unit 6h). 'Montane Heath' (map unit 21c), foreground, predominates on the plateau surface.

deep, moist, fertile clay loams derived from the Tertiary basalt that caps these peaks. The adjacent sandstone gullies receive clay and nutrients in downwash from the basalt. More exposed areas of basalt support eucalypt tall open-forest (map unit 6g). Rainforest is also found in the sheltered gully of Pulpit Hill Creek, west of Blackheath, where the soils are enriched from shale bands of the Illawarra Coal Measures.

The dominant trees are *Ceratopetalum apetalum* and *Doryphora sassafras* with *Quintinia sieberi, Acmena smithii, Hedycarya angustifolia* and *Atherosperma moschatum*, the last two species indicating a Cool Temperate influence at the highest elevations. *Callicoma serratifolia* is abundant in the sandstone gullies but absent from the basalt (McLuckie & Petrie 1926).

The understorey also varies depending on the bedrock. The tree ferns, *Dicksonia antarctica* and *Cyathea australis* predominate on the basalt soil with a very sparse and patchy groundcover of herbs such as *Geranium solanderi* var. *solanderi* and *Centella asiatica* and smaller ferns including *Blechnum cartilagineum, Polystichum proliferum, Pellaea falcata* var. *falcata, Doodia aspera, Pteridium esculentum* and *Sticherus flabellatus*. There are also a number of climbers including *Pandorea pandorana, Tylophora barbata, Clematis aristata* and *Smilax australis*. In sandstone gullies the tree fern stratum is less important, allowing a more diverse understorey to develop. The shrubs *Polyscias sambucifolia, Elaeocarpus reticulatus, Lomatia myricoides* and *Prostanthera lasianthos* are more common. Detailed descriptions of this community at Mt Wilson are given by Brough, McLuckie & Petrie (1924), Petrie (1925), McLuckie & Petrie (1926) and Floyd (1984).

Less species-rich rainforests occur as narrow bands along creeks on the escarpment slopes. These are too small in area to be mapped at 1:100 000 scale and are included in the 'Escarpment complex' (unit 6h).

Map unit 8d 'Kowmung Dry Rainforest'.

Closed-forest: *Toona australis– Ehretia acuminata-Brachychiton populneum*.

Small patches of dry rainforest are found in the Kowmung wilderness, a deeply dissected, low-rainfall area of Devonian metamorphic rocks in the south-western part of the map sheet. The rainforest is restricted to small patches on the lower sheltered slopes of gorges between 300 and 700 m elevation. The largest stand occupies the south-facing slopes of Kanangra Gorge and resembles rainforest described by Floyd (1984) at Mt Colboyd further south. Numerous occurrences along the Kowmung River and its tributaries are too small to be mapped at 1:100 000 scale and are included within the 'Kowmung Wilderness Complex' (map unit 10p).

The major tree species are *Toona australis, Ehretia acuminata* and *Brachychiton populneum*, though a number of others are frequent. These include *Ficus rubiginosa, Dendrocnide excelsa, Alectryon subcinereus, Claoxylon australe* and *Backhousia myrtifolia*. The understorey contains shrubs of *Hymenanthera dentata, Rapanea howitteana, Notelaea longifolia, Trema aspera, Derringia amaranthoides, Pomaderis aspera* and *Seringia arborescens*. There are few vines, the main species being *Eustrephus latifolius, Aphanopetalum resinosum, Celastrus australis, Pandorea pandorana, Marsdenia flavescens and M. rostrata*. The sparse goundcover includes the ferns *Adiantum aethiopicum, Asplenium flabellifolium, Doodia aspera, Pteris tremula* and *Pellaea falcata*, herbs *Urtica incisa, Stellaria flaccida, Plectranthus parviflorus, Sigesbeckia orientalis, Hydrocotyle geraniifolia* and the grass, *Oplismenus aemulus*.

Adjacent dry slopes often support a 'blue bush' scrub with *Acacia binervia, A. falciformis* and the rare *A. clunies-rossii*.

Map unit 9a 'Shale Cap Forest'.

Open-forest: *Eucalyptus notabilis–E. globoidea– Syncarpia glomulifera*.

Along the Bilpin ridge are the most western remnants of the Wianamatta Shale cappings. Here, on the deep, relatively well-drained clay soils is an open-forest with *E. notabilis, E. globoidea* and *Syncarpia glomulifera. Eucalyptus piperita* ssp. *piperita* may be common where there is some sandstone influence. Wetter sites support *E. cypellocarpa* at the higher western end, while *E. deanei* and *E. punctata* occur further east. The understorey contains shrubs of *Acacia parramattensis, Indigofera australis, Hibbertia aspera* and *Helichrysum diosmifolium* with a moderately dense groundcover of the grasses *Entolasia marginata, Dichelachne rara, Echinopogon ovatus*, the herbs *Helichrysum elatum, Poranthera microphylla, Dichondra repens, Dianella caerulea*, and twiners including *Hardenbergia violacea, Kennedia rubicunda, Tylophora barbata* and *Eustrephus latifolius*. Because of their reasonably good agricultural soils, the natural vegetation of these shale cappings has been largely cleared for orchards and small farms.

Map unit 9i 'Blue Mountains Sandstone Plateau Forest'.

Open-forest: *Eucalyptus sieberi–E. piperita*.

Much of the Triassic sandstone plateau at higher altitudes (800 to 1150 m) is covered by an open-forest dominated by *E. sieberi* and *E. piperita* ssp. *piperita*. The soils are shallow, sandy, low in nutrients, well-drained and derived from Narrabeen Group sandstones. Taller variants of this community with *E. oreades, E. piperita* ssp. *piperita, E. sieberi* and *E. radiata* ssp. *radiata* occur in more sheltered situations, while *E. sieberi, E. sclerophylla, E. oblonga* and *E. mannifera* ssp.

gullickii dominate more exposed areas. The understorey is shrubby and includes such species as *Leptospermum attenuatum, Petrophile pulchella, Banksia ericifolia, B. spinulosa* var. *spinulosa, B. spinulosa* var. *cunninghamii, Persoonia chamaepitys* and *Acacia terminalis.*

The lower altitudinal limit of 800 m where this unit adjoins map unit 10a is concurrent with the margins of the higher elevation plateau and coincides with the distributional limits of a number of species. For example low altitude species such as *Angophora costata* ssp. *costata, E. gummifera, Syncarpia glomulifera, Acacia linifolia* and *Hibbertia empetrifolia* are common in map unit 10a but not in 9i, while higher altitude species such as *E. oreades, E. mannifera* ssp. *gullickii, E. radiata* ssp. *radiata, Banksia spinulosa* var. *cunninghamii, Persoonia chamaepitys, P. myrtilloides, Boronia microphylla* and *Stellaria pungens* occur in map unit 9i but not in 10a.

Escarpments associated with the Coxs, Kedumba and Grose River valleys form a more distinct boundary to this community. Species such as *E. oreades, E. dendromorpha, E. radiata* ssp. *radiata* and *Banksia spinulosa* var. *cunninghamii* are often associated with clifflines and may extend over the escarpment edge for varying distances.

Map unit 9j 'Montane Gully Forest'.

Open-forest: *Eucalyptus fastigata–E. cypellocarpa–E. dalrympleana.*

This community occupies moderate to steep, sheltered slopes and narrow gorges below the Triassic sandstone escarpments at elevations of 850 to 1100 m. It is a high altitude variant of map unit 6h and occurs on similar soils and geology (Illawarra Coal Measures). The boundary between these communities is poorly defined and for mapping purposes the 850 m contour has been used. This approximates the upper distributional limits of *Angophora costata* ssp. *costata* and *Syncarpia glomulifera* in map unit 6h, and the lower limits of *E. fastigata, E. dalrympleana* ssp. *dalrympleana* and *E. blaxlandii* in the higher altitude map unit 9j. The boundary has been mapped arbitrarily to the west of Mt Victoria township.

Eucalyptus fastigata, E. cypellocarpa and *E. dalrympleana* ssp. *dalrympleana* are dominant with *E. oreades, E. blaxlandii, E. radiata* ssp. *radiata* and *E. sieberi* in various combinations. The understorey is moderately shrubby with *Acacia terminalis, A. buxifolia, Oxylobium ilicifolium* and *Leptospermum flavescens* together with grasses and ferns such as *Culcita dubia.*

Disturbances in Community 9j include selective logging, numerous small coal and shale mines (now mostly abandoned) and landslides, particularly near Hassans Walls.

Map unit 9m 'Megalong Forest'.

Open-forest: *Angophora costata–Eucalyptus punctata–E. sieberi.*

This occurs on well-drained sandy loams derived from sandstones, conglomerates and shales of the Permian Shoalhaven Group. It covers undulating country beyond the escarpment slopes of Narrow Neck Peninsula at 400 to 750 m elevation and is also found around Mt Cookem. *Angophora costata* ssp. *costata, E. punctata* and *E. sieberi* are dominant with *E. piperita* ssp. *piperita, E. agglomerata, E. oblonga, E. eugenioides* and *E. sclerophylla* in various combinations.

The understorey includes scattered shrubs of *Persoonia linearis, P. levis, Banksia spinulosa* var. *spinulosa, Acacia obtusifolia, A. linifolia, Lomatia silaifolia, Isopogon anemonifolius* and *Leptospermum attenuatum* with a more continuous ground cover of *Lomandra longifolia, Stypandra glauca, Lepidosperma laterale* and grasses such as *Stipa pubescens, Echinopogon caespitosus, Dichelachne rara* and *Microlaena stipoides* var. *stipoides.* A more mesic understorey with occasional trees of *E. cypellocarpa* may be found in sheltered situations and where this community adjoins map unit 6h. On more clayey soils at lower elevations it is replaced by 10q.

Map unit 9n 'Montane Moist Forest'.

Open-forest: *Eucalyptus fastigata–E. dalrympleana–E. viminalis.*

The predominant plant communities at high altitudes west of Coxs River may be found on several geological formations. On moist, fertile, relatively deep clay loams and sandy loams is an open-forest characterized by *E. fastigata* and *E. dalrympleana* ssp. *dalrympleana*, occasionally with *E. viminalis, E. radiata* ssp. *radiata* and *E. bicostata* (Figure 3). *Eucalyptus viminalis* occurs sporadically on undulating terrain, but is mainly confined to creeks, while *E. radiata* ssp. *radiata* may be found on some ridgetops and where this map unit (9n) adjoins 10s. *Eucalyptus bicostata* is only found in small localized patches, for example on Binoomea Ridge, above Jenolan Caves.

The understorey includes scattered shrubs of *Acacia melanoxylon, Lomatia myricoides, Indigofera australis* and *Swainsona galegifolia*, with a continous groundcover of herbs such as *Geranium potentilloides* var. *abditum, Stellaria pungens, Hydrocotyle acutiloba, Lomandra longifolia, Gnaphalium gymnocephalum, Polystichum proliferum* and numerous grasses including *Poa labillardieri* and *Dichelachne rara*. Black (1976) recorded *E. obliqua* on the lower slopes of gullies on the eastern part of the Boyd Plateau, while the rare *E. macarthurii* can be found around the Boyd Crossing.

Community 9n may occur on Devonian rhyolites and rhyo-dacites, folded Devonian quartzites, siltstones and claystones of the Lambie Group, Silurian tuff, limestone, siltstone, phyllite and shale, and occasionally on Carboniferous adamellites, granites and granodiorites of the Kanimbla Batholith. It is most widespread on steep, sheltered slopes and gullies on the folded Devonian rocks, but also occurs on more gentle slopes of the Boyd Plateau where *E. fastigata* has been extensively logged.

Map unit 9x 'River Oak Forest'.

Open-forest: *Casuarina cunninghamiana.*

Narrow bands of *Casuarina cunninghamiana* can be found along the alluvial banks of the Coxs River. These consist of mobile gravels and sands, periodically flooded, and support little other plant life apart from short-lived exotic species such as *Conyza albida* and *Hypochoeris radicata*. The banks have a number of exotic species most notably *Conium maculatum* and *Rubus fruticosus*. The surrounding land has almost always been cleared for agriculture.

Map unit 10a 'Sydney Sandstone Complex'.

This widespread vegetation complex is found on the low elevation (<800 m) sandstone plateaux. Floristics and structure vary, depending on physiography, rainfall, altitude, aspect and local soil conditions. Two subunits have been recognized: 10ag, moist forests associated with sheltered hillsides and gullies; and 10ar, drier woodlands associated with the more exposed ridges and plateau tops. There is considerable overlap between these subunits and both grade into the higher altitude sandstone vegetation (map unit 9i) above 800 m elevation. The transition between map units 10a and 9i is discussed in the description of the latter.

Subunit 10ag Open-forest: *Angophora costata–Eucalyptus piperita–E. agglomerata–Syncarpia glomulifera.*

This subunit occurs in sheltered gullies with moist, well-drained, shallow sandy loams on Hawkesbury and Narrabeen Group sandstones. Open-forest is common on upper slopes and in the more shallow gullies. Tree species include

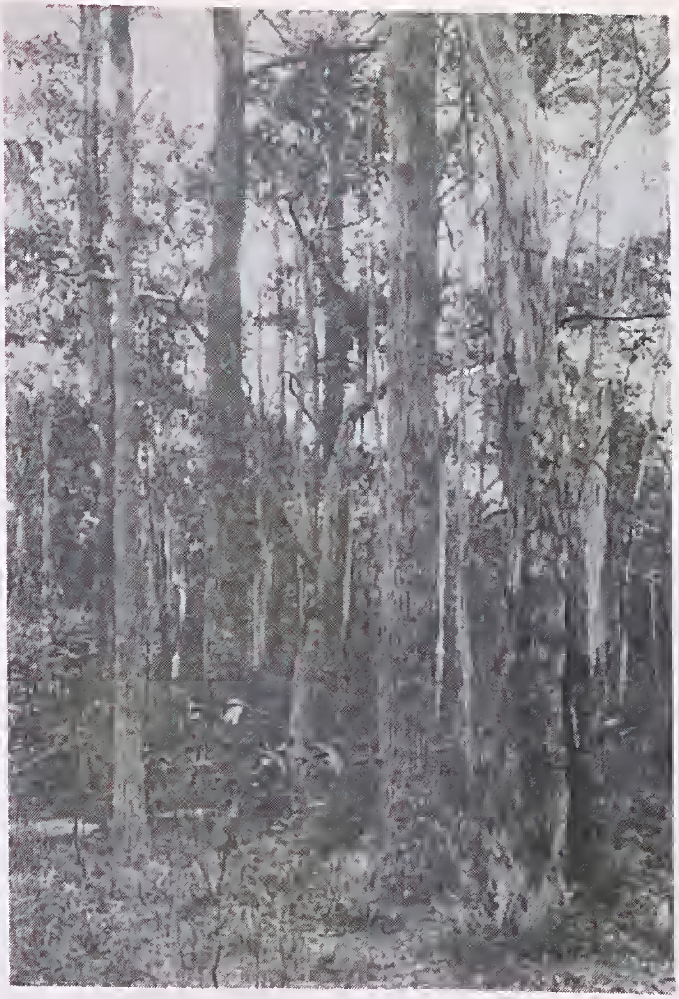

Figure 3. 'Montane Moist Forest' (map unit 9n) with rough-barked *Eucalyptus fastigata* and ribbons of decorticating bark on *E. dalrympleana* ssp. *dalrympleana* (on the right) on the Boyd Plateau near Krungle Bungle Range. The small trees are regrowth after logging. The herbaceous understorey includes the fern *Blechnum cartilagineum*.

Angophora costata ssp. *costata*, *E. piperita* ssp. *piperita*, *E. agglomerata* and *Syncarpia glomulifera* occasionally with *E. gummifera*. The understorey includes small trees of *Allocasuarina torulosa* and *Acacia elata* with shrubs *Hakea dactyloides* (single-stemmed form), *Pultenaea flexilis* and *Dodonaea triquetra*. Tall open-forest is restricted to the more sheltered gorges and is dominated by *E. deanei* with *Syncarpia glomulifera*, *Acacia elata*, *Ceratopetalum apetalum*, *Callicoma serratifolia* and *Angophora floribunda*. There is a distinctive riparian scrub of *Tristaniopsis laurina* and *Backhousia myrtifolia* along the larger watercourses.

Subunit 10ar Woodland: *Eucalyptus gummifera–E. sclerophylla–E. oblonga*.

This subunit is widespread on ridges and open slopes on shallow, well-drained, sandy soils on Hawkesbury and Narrabeen Group sandstones. Structurally, it is woodland or low woodland with trees of *E. gummifera*, *E. sclerophylla* and *E.*

oblonga, though *E. punctata*, *E. piperita* ssp. *piperita* and *Angophora costata* ssp. *costata* may also be present in more sheltered sites. *Eucalyptus sclerophylla* is particularly common in damper soils. The understorey is rich in shrubs of the Proteaceae, Myrtaceae and Fabaceae including *Banksia spinulosa* var. *spinulosa*, *Hakea dactyloides* (multi-stemmed form), *Persoonia levis*, *Leptospermum attenuatum*, *Kunzea ambigua*, *Pultenaea elliptica* and *Acacia linifolia*.

Map unit 10h 'Tablelands Grassy Woodland Complex'.

Woodland: *Eucalyptus dives–E. mannifera–E. eugenioides*.
Woodland: *E. pauciflora–E. rubida*.
Woodland: *E. aggregata–E. mannifera–E. stellulata*.

Above 800 m elevation on the undulating country of the upper Coxs River valley, on Shoalhaven Group geology, is a toposequence of communities. Woodland is widespread on well-drained gentle slopes and low hills. It is dominated by *E. dives*, *E. mannifera* ssp. *mannifera* and *E. eugenioides* with some *E. cypellocarpa* from the adjoining escarpment slope vegetation (map unit 9j). Grasses dominate the understorey, particularly *Dichelachne rara*, *Danthonia pilosa*, *Aristida ramosa* and *Stipa mollis* with emergent shrubs of *Acacia buxifolia*, *A. falciformis*, *Banksia marginata*, *Exocarpos cupressiformis* and *Daviesia latifolia*.

Eucalyptus pauciflora ssp. *pauciflora* and *E. rubida* occur in frost hollows, while the more poorly drained depressions, for example at Butlers Creek, may support a woodland of *E. aggregata*, *E. mannifera* ssp. *mannifera* and *E. stellulata* with *Leptospermum myrtifolium* in the understorey. *Eucalyptus viminalis* is common along creek banks.

This map unit has been mostly cleared for agriculture in the Hartley–Hartley Vale area.

Map unit 10l 'Snow Gum Woodland'.

Woodland: *Eucalyptus pauciflora–E. dalrympleana*.
Woodland: *E. pauciflora–E. rubida–E. stellulata*.

This unit is found at the highest altitudes on the map sheet (above 1100 m), on shallow to moderately deep loams and sandy loams derived from a variety of parent rock types, particularly acidic igneous rocks of the Kanimbla Batholith, quartzites of the Devonian Lambie Group, and more rarely on sandstones of the Shoalhaven Group.

The *E. pauciflora* ssp. *pauciflora–E. dalrympleana* ssp. *dalrympleana* woodland is found on small, exposed, rocky ridgetops west of Hampton (e.g. Mt Bindo 1364 m). The understorey consists of occasional shrubs of *Acacia dealbata* with a continous groundcover of herbs and grasses such as *Stellaria pungens*, *Acaena novae-zelandiae*, *Poranthera microphylla*, *Geranium* spp., *Plantago* spp., *Poa sieberiana* and *P. labillardieri*. Patches of *Lomandra longifolia* and *Pteridium esculentum* may be common.

This community is more widespread on the Boyd Plateau on undulating country, particularly where cold air drainage is significant. In hollows where drainage is poor *E. stellulata–E. pauciflora* ssp. *pauciflora* woodland occurs. *Eucalyptus rubida* may be found on the cold, dry sites (Black 1976). This unit is related to 10h.

Map unit 10m 'Mount Walker Complex'.

Woodland: *Eucalyptus macrorhyncha–E. melliodora*.

This community is found west of Lithgow and south of Hartley on dissected country at altitudes above 600 m. It is mostly on well-drained sandy loams derived from quartzite, sandstone, siltstone and claystone of the Lambie Group, but also on clays derived from a small outcrop of carboniferous gabbro. West of Lithgow

E. dives, E. viminalis and *E. bridgesiana* characterize the gullies, while *E. rossii, E. mannifera* ssp. *praecox* and *E. dives* occur on the ridges. South of Hartley there are fewer tree species. Here, *E. macrorhyncha* and *E. melliodora* occur throughout, with occasional *E. mannifera* and *E. bridgesiana* on the ridges and upper slopes.

The understorey includes scattered shrubs of *Lissanthe strigosa* and *Persoonia linearis* with a discontinuous ground cover of the grasses *Poa labillardieri, Chionochloa pallida, Aristida ramosa* and *Stipa rudis* ssp. *rudis*, and herbs including *Geranium solanderi* var. *solanderi, Hydrocotyle laxiflora, Stellaria pungens, Senecio lautus* ssp. *dissectifolius* and *Cheilanthes sieberi*.

Map unit 10o 'Yellow Box Woodland'.

Woodland: *Eucalyptus melliodora–E. viminalis*.

Much of the undulating granite country supporting this community was extensively cleared for agriculture early in the nineteenth century. Remnants may be found in the Coxs River valley at elevations between 250 and 850 m on deep, well-drained sandy soils derived from Carboniferous adamellite, granite and granodiorite.

Eucalyptus melliodora and *E. viminalis* are the most characteristic tree species, although *E. eugenioides* is particularly common east of Coxs River and *E. bridgesiana* may be found in patches throughout. *Eucalyptus dalrympleana* ssp. *dalrympleana* occurs at the higher elevations, while *Angophora floribunda* is often near watercourses or on the slopes nearby. The understorey has scattered shrubs of *Exocarpos cupressiformis, Bursaria spinosa* and *Lissanthe strigosa* with an open ground cover of grasses such as *Themeda australis, Poa labillardieri, Cymbopogon refractus* and *Echinopogon caespitosus*, and herbs including *Geranium solanderi* var. *solanderi, Hypericum gramineum* and *Lomandra glauca*.

On rocky, granite sites to the north, around Lyall Dam, *Eucalyptus dives* is particularly common and the understorey includes a greater variety of shrub species including *Banksia marginata, Platysace lanceolata, Daviesia latifolia, Dodonaea viscosa* and *Cassinia quinquefaria*.

Most of the remaining areas of Community 10o are fragmented, grazed by stock and rabbits, and weed-infested to varying degrees.

Map unit 10p 'Kowmung Wilderness Complex'.

Woodland: *Eucalyptus tereticornis–E. melliodora*.

Woodland: *E. fibrosa–E. crebra–E. eugenioides–E. punctata*.

This unit occupies a large inaccessible area of deeply dissected country with narrow ridges, steep slopes and gullies in the lower Coxs and Kowmung valleys (Figure 4). Elevation ranges from 150 to 900 m. The soils are well-drained clay loams derived from quartzites, sandstones, siltstones and claystones of the Devonian Lambie Group.

Eucalyptus tereticornis is common on moist slopes and in gullies, often with *E. melliodora*, and occasionally *E. quadrangulata. Angophora floribunda* and *E. viminalis* may be found near watercourses. The understorey is variable, though typically contains shrubs of *Bursaria longisepala, B. spinosa, Breynia oblongifolia, Lissanthe strigosa* and *Persoonia linearis* with numerous herbs including *Dichondra repens, Pratia purpurascens, Senecio lautus* ssp. *dissectifolius* and *Wahlenbergia* spp., twiners such as *Desmodium varians* and *Glycine* spp., the ferns *Cheilanthes sieberi* and *C. distans* and grasses such as *Themeda australis, Dichelachne micrantha, Oplismenus imbecillus* and *Panicum effusum*. In the east, *E. deanei* is found in moist gullies with *Angophora floribunda, E. tereticornis* and *Syncarpia glomulifera*. Occasional patches of dry rainforest (map unit 8d) may include *Toona australis*, though they are more usually dominated by *Backhousia myrtifolia*. More comprehensive field traverses would provide more data on vegetation patterns in this extensive, poorly known area.

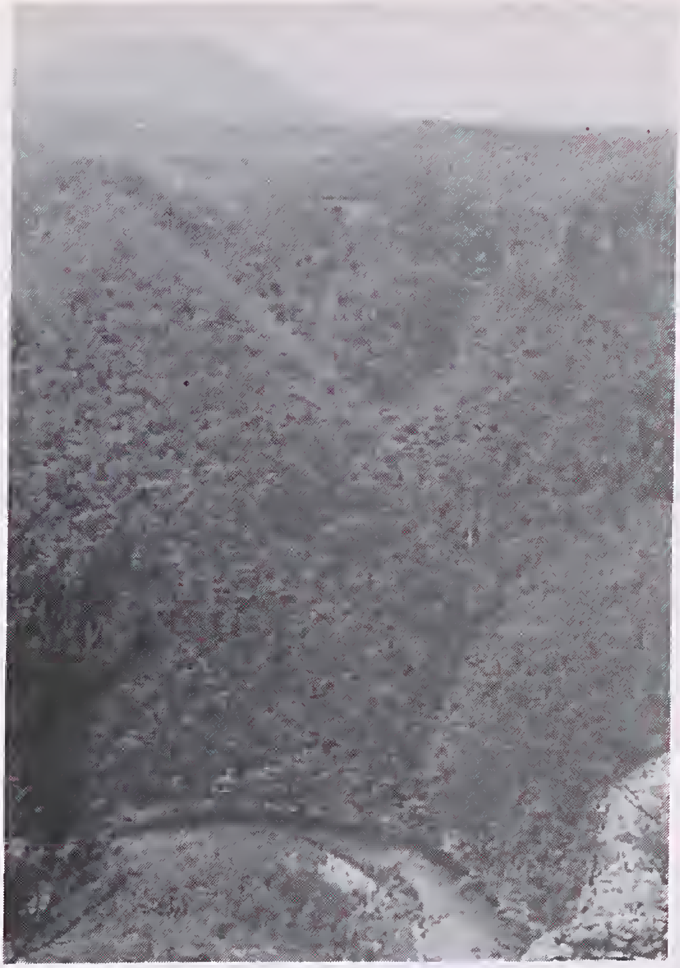

Figure 4. View northwest from Mt Cookem with Coxs River in the foreground. Eucalypt woodland in the 'Kowmung Wilderness Complex' (map unit 10p) occurs on the sides of the gorge. Note the closed canopies of *Backhousia myrtifolia* along the tributary creek, and emergent trees of *Eucalyptus deanei* nearby. The plateau surface supports 'Megalong Forest' (map unit 9m), while the slopes of the Wild Dog Mountains (background) support 'Escarpment Complex' tall open-forest (map unit 6h).

Map unit 10q 'Burragorang Ironbark Woodland'.

Woodland: *Eucalyptus crebra–E. eugenioides–E. punctata–E. fibrosa.*
Woodland: *E. sclerophylla–Angophora bakeri.*

This map unit occupies the Shoalhaven Group shales, conglomerates and sandstones below 500 m elevation, on the undulating country of the Kedumba Valley, Scotts Main Range and the Bimlow area. Gentle to moderate slopes and gullies with well-drained, loamy soils support a woodland of *E. eugenioides, E. crebra* and *E. punctata*, occasionally with *E. fibrosa* ssp. *fibrosa* and *E. agglomerata*. The understorey is open with scattered shrubs including *Jacksonia scoparia, Persoonia linearis, Acacia buxifolia, Grevillea obtusifolia* and *Lissanthe strigosa* and a ground cover of *Stypandra glauca, Lomandra longifolia, Themeda australis, Aristida vagans* and *Imperata cylindrica.*

Trees of *E. tereticornis*, with shrubs of *Melaleuca linariifolia* and a grassy understorey are found on damp, low-lying clay-loam soils and in gullies.

Exposed rocky ridges with shallow, sandy soils and western aspects, support woodland of *E. sclerophylla* and *Angophora bakeri* ssp. *bakeri* and an understorey of low shrubs including *Banksia spinulosa* var. *spinulosa, Leptospermum parvifolium, Dillwynia retorta, Mirbelia rubiifolia, Phyllanthus thymoides* and *Daviesia acicularis*. Grasses incude *Stipa pubescens* and *Aristida warburgii*.

Map unit 10r 'Residual Sandstone Woodland'.

Woodland: *Eucalyptus sieberi–E. blaxlandii.*

This community is found in well-drained, shallow, sandy soils on residual sandstone cappings of the Shoalhaven Group, folded sandstones of the Devonian Lambie Group and occasionally on Carboniferous granites. There are small occurrences at elevations above 900 m along moderately exposed, rocky ridges and plateau edges west of Coxs River, for example Table Mountain and parts of Black Range. *Eucalyptus sieberi* and *E. blaxlandii* are the dominant tree species here, though the latter may be absent from some sites. *Eucalyptus cypellocarpa* occurs on parts of Gibraltar Rocks and Black Range (Figure 5). Understorey shrubs include *Leptospermum attenuatum, Banksia marginata, B. spinulosa* var. *spinulosa, Persoonia linearis, P. laurina, Acacia obtusifolia, A. obliquinervia, Oxylobium ilicifolium, Leucopogon lanceolatus* var. *lanceolatus, Brachyloma daphnoides, Monotoca scoparia* and *Platysace lanceolata*. Ground cover species include *Gonocarpus tetragynus, Pomax umbellata, Lomandra glauca, L. longifolia* and *Patersonia glabrata*. The shrubby understorey and low frequency of grasses distinguishes Community 10r from other high altitude vegetation types in the area.

Though more common on sandstone of the Shoalhaven Group, this community is also found on sandstone facies of the Lambie Group on narrow rocky ridges such as Krungle Bungle Range and the eastern end of Black Range. Flatter sites on the Shoalhaven Group sandstones (e.g. the western end of Black Range) are occupied by map unit 10s which is more widespread on the Lambie Group metamorphics and Carboniferous granites. Intermediate sites support *E. sieberi* and *E. radiata* ssp. *radiata* with an understorey mostly of grasses and scattered shrubs.

The most northern occurrence of Community 10r is west of Old Bowenfels where residual sandstone of the Illawarra Coal Measures caps a remnant of Shoalhaven Group sandstone. *Eucalyptus sieberi* is the only tree species on the upper part of this outcrop, while on the lower slopes it occurs with *E. dives*. The latter may be a remnant of Community 10h which probably once grew on the flat surrounding country now cleared for agriculture.

Map unit 10s 'Montane Woodland'.

Woodland: *Eucalyptus radiata–E. dalrympleana.*

Woodland: *E. ovata–E. stellulata.*

This map unit is found on flat to undulating country, west of Coxs River, at elevations above 900 m. It occurs on well-drained to damp sandy loams on various parent rocks including quartzite, sandstone, siltstone and claystone of the Lambie Group (Devonian), adamellite, granite and granodiorite of the Kanimbla Batholith (Carboniferous) and shale, conglomerate and sandstone of the Shoalhaven Group (Permian). It is most widespread on the Devonian parent material on moderate slopes, though generally more luxuriant on the Carboniferous granites. On both types of geology it grades into unit 9n in sheltered sites.

Black (1976) described this community in her survey of the Boyd Plateau. *Eucalyptus radiata* ssp. *radiata and E. dalrympleana* ssp. *dalrympleana* are the

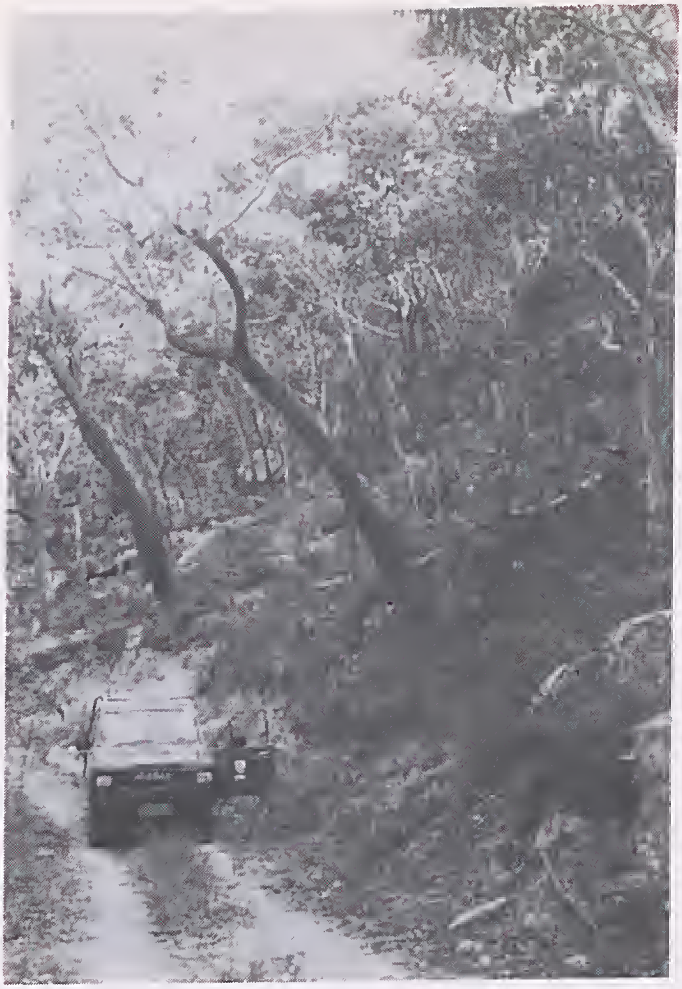

Figure 5. Woodland with *Eucalyptus sieberi, E. cypellocarpa* and a shrubby understorey interspersed with clumps of *Poa* sp. on granite at Moorara Boss, nothern Boyd Plateau (map unit 10r).

dominant canopy species, though there are significant numbers of *E. dives* on the north-western part of the Boyd Plateau, and *E. pauciflora* ssp. *pauciflora* may be found sporadically throughout, particulary at higher elevations (Figure 6). The understorey includes scattered shrubs of *Acacia obliquinervia, Leucopogon lanceolatus* var. *lanceolatus, Lomatia myricoides* and *Persoonia oxycoccoides* with a relatively continuous ground cover of grasses such as *Poa sieberiana, P. labillardieri* and *Dichelachne rara* and herbs such as *Lomandra longifolia, Gonocarpus tetragynus, Wahlenbergia communis* and *Hydrocotyle* sp.

Trees of *E. ovata*, sometimes with *E. stellulata* , are found in poorly-drained depressions. The understorey includes *Leptospermum obovatum, Gahnia sieberiana, Juncus melanobasis, Restio fimbriatus* and *Blechnum minus.*

Map unit 10t 'Mount Blaxland Complex'.

Woodland: *Eucalyptus sieberi–E. pulverulenta.*

Found on shallow sandy loams, this vegetation is restricted to the steep, rocky knolls on Mt Blaxland and Wentworths Sugarloaf (west of Hartley) and an outcrop of Devonian rhyolite near Lowther. A woodland dominated by *E. sieberi, E. rossii* and *E. oblonga* with the shrubby *E. pulverulenta* as an understorey species is most common, though in places the trees are absent, leaving *E. pulverulenta* in open-heath vegetation (T. J. Fatchen, pers. comm.). *Eucalyptus pulverulenta* occurs naturally only in the Hartley district and at Cowra Creek, east of Bredbo (Pryor 1981).

The understorey consists of an open shrub layer of *Persoonia linearis, Dodonaea viscosa, Bursaria spinosa, Platysace lanceolata, Acacia verniciflua, A. buxifolia* and *Oxylobium ilicifolium* with a ground cover of grasses including *Themeda australis, Poa* spp., *Danthonia* spp., and *Stipa* sp., and herbs such as *Stypandra glauca, Dianella revoluta, D. caerulea, Lomandra longifolia, L. multiflora* and *Helichrysum bracteatum* (T. J. Fatchen, pers. comm.).

Map unit 10u 'Jenolan Granite Woodland'.

Woodland: *Eucalyptus punctata–E.* sp. nov. 'MAHEK'– *E. sieberi.*

A granite outlier of the Kanimbla Batholith on the steep, north-facing slope of Jenolan Gorge supports this distinctive and diverse woodland community which grades into Community 10r on the highest parts of the outcrop (>1000 m). The soils are relatively deep, freely draining and sandy. Open situations are occupied by *E. punctata, E.* sp. nov. 'MAHEK' and *E. sieberi with some E. goniocalyx* at higher elevations while *E. melliodora, E. agglomerata, E. cypellocarpa, E. punctata* and *Angophora floribunda* may be found in more sheltered situations in various combinations.

The understorey is predominantly shrubby with *Exocarpos strictus, Dillwynia retorta, D. acicularis, Bossiaea obcordata, Banksia spinulosa* var. *spinulosa, Grevillea arenaria, Platysace lanceolata, Leptospermum parvifolium, L.* sp. nov. 'X', *Leucopogon muticus, Teucrium corymbosum* and *Xanthorrhoea australis.* This is also an interesting disjunct Tableland locality for *Melaleuca armillaris,* essentially a coastal species, first collected from Jenolan Gorge by Blakely in 1900.

Map unit 17a 'Black Range Scrub'.

Open-scrub: *Eucalyptus mannifera–Leptospemum myrtifolium– L.* sp. nov. 'A'–*Patersonia fragilis.*

On the gentle southern slopes of Black Range are several small, poorly-drained areas with rather humic, loamy soils overlying metamorphic rocks of the Devonian Lambie Group. Shrubs of *Leptospermum myrtifolium* and *L.* sp. nov. 'A' predominate here with occasional small trees of *E. mannifera* ssp. *mannifera, E. dalrympleana* ssp. *dalrympleana* and *E. stricta.* Sedges such as *Gahnia sieberiana, Schoenus apogon, Empodisma minus* with other moisture tolerant herbs including *Patersonia fragilis, Gonocarpus micranthus* ssp. *micranthus* and *Viola hederacea* comprise the gound cover.

This community resembles the swamps of the Boyd Plateau (map unit 26b), though the latter lack eucalypts and are more thickly vegetated with *Carex* spp. and *Juncus* spp., probably due to greater waterlogging.

Map unit 20a 'Newnes Plateau Shrub Swamps'.

Closed-heath: *Leptospermum lanigerum–Baeckea linifolia–Grevillea acanthifolia–Xyris ustulata.*

In shallow headwater valleys above 1000 m elevation on the Triassic sandstone plateau, swamps with poorly-drained, acid, sandy peat soils have developed. On the Katoomba 1:100 000 map sheet these are restricted to the Bell area, although their best development is on the Newnes Plateau to the north.

These swamps are dominated by a closed-heath of *Leptospermum lanigerum, Baeckea linifolia, Grevillea acanthifolia* and *Epacris paludosa* with a ground cover

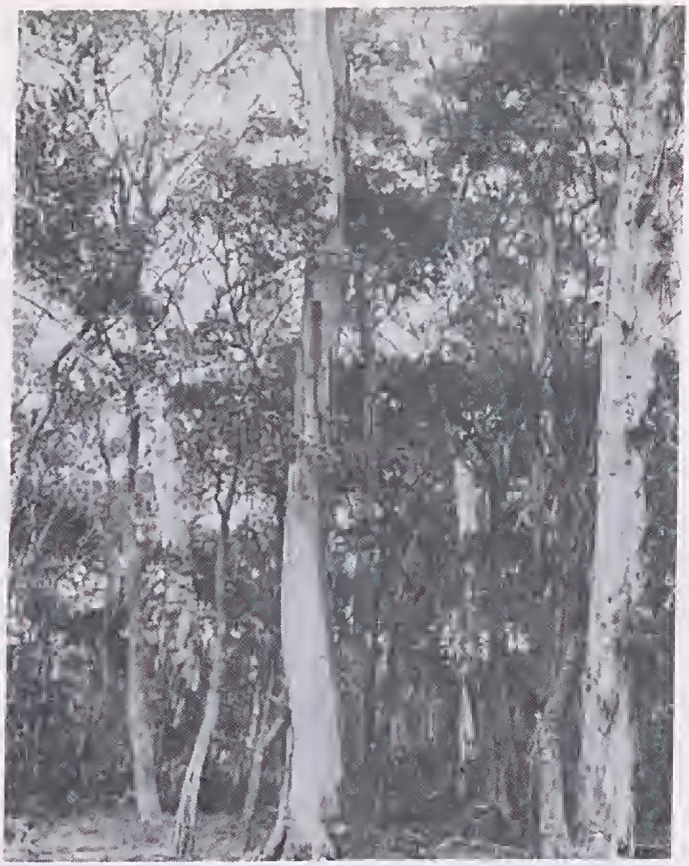

Figure 6. *Eucalyptus radiata* ssp. *radiata* (rough barked) and *E. dalrympleana* ssp. *dalrympleana* (smooth barked) with a grassy understorey of *Poa sieberiana* in 'Montane Woodland' (map unit 10s) near Sally Camp Creek on the Boyd Plateau.

of sedges including *Restio australis, Empodisma minus, Lepyrodia scariosa, L. anarthria, Lepidosperma limicola* and *Patersonia fragilis.* Floristic composition varies according to soil type and waterlogging regime. Adjacent to drainage lines there may be particularly thick growth of *Gymnoschoenus sphaerocephalus* and *Gleichenia dicarpa*, while in relatively drier, more open sites are small herbs such as *Hydrocotyle acicularis, Viola hederacea, Gonocarpus tetragynus* and *Xanthosia dissecta.*

Where the soils have a higher clay content these swamps contain a number of species also found in the swamps of the Boyd Plateau (map unit 26b) including *Leptospermum myrtifolium, L. flavescens, Callistemon sieberi, Juncus continuus* and, in drier places, *Lomandra longifolia.*

Map unit 20b 'Coxs River Swamps'.

Closed-heath: *Leptospermum obovatum–L. juniperinum–Grevillea acanthifolia.*

Filled with rather clayey, organic sediments derived from the Illawarra Coal Measures, these swamps occur where creeks draining the Triassic sandstone plateau dump their sediment load at the base of the escarpment. They support a simple flora dominated by *Leptospermum obovatum, L. juniperinum* and

Grevillea acanthifolia with a dense groundcover of *Carex* spp. and *Juncus* spp. Kerosene Creek at Hartley Vale and smaller swamps near Nellies Glen are the only examples in the area covered by the Katoomba 1:100 000 map sheet, though others are found in the headwaters of Coxs River to the north. Grazing at Kerosene Creek has led to the invasion of some exotic species and some damage due to trampling by stock.

Map units 21c & 21f 'Open-heath'.

Heath is found on exposed ridgetops, upper slopes with western aspects and often above the escarpment cliffs on the Triassic sandstone plateau (Figures 2 and 7). It occupies an altitudinal range from 600 to 1250 m. The soils are well drained to periodically damp, skeletal, pale and sandy, low in nutrients and derived from Narrabeen Group Sandstones.

Throughout the broad geographical and altitudinal range of the heath communities a number of species are common, particularly the shrubs *Eucalyptus stricta, Allocasuarina nana, Leptospermum attenuatum, Isopogon anemonifolius, Petrophile pulchella, Lambertia formosa, Conospermum taxifolium, Hibbertia cistiflora* and *Platysace linearifolia*, and ground cover species such as *Lepidosperma viscidum, Schoenus villosus, Entolasia stricta, Lomandra glauca, Gonocarpus tetragynus, Dampiera stricta, Goodenia bellidifolia* and *Sowerbaea juncea*. In contrast, the distributions of many other species are more restricted and form part of an overall altitudinal gradation in species composition. An elevation of 850–900 m has arbitrarily been chosen to separate the high and low altitude heath communities, coded 21c and 21f respectively.

Map unit 21c 'Montane Heath'.

Open-heath: *Eucalyptus stricta–Allocasuarina nana–Leptospermum attenuatum–Phyllota squarrosa–Eriostemon obovalis.*

Open-heath: *Epacris reclinata–Dracophyllum secundatum–Gleichenia rupestris.*

High elevation heath may be found on Narrabeen Group sandstones from Narrow Neck Peninsula to the Newnes Plateau in the north, particularly on Flat Top, Hat Hill, around Blackheath, the Mt Banks–Bell area and Hassans Walls. The dominant shrubs include *Eucalyptus stricta, Allocasuarina nana* and *Leptospermum attenuatum* with prominent ground cover species such as *Schoenus villosus, Lepidosperma viscidum, Patersonia sericea* and *Goodenia bellidifolia.* Species restricted to higher elevations include *Eriostemon obovalis, Boronia anemonifolia, B. microphylla, Acacia gunnii, Mirbelia platyloboides, Phyllota squarrosa, Pultenaea canescens, Darwinia taxifolia* ssp. *taxifolia, Eucalyptus mannifera* ssp. *gullickii, Petrophile canescens, Pseudanthus divaricatissimus* and *Omphacomeria acerba.*

A distinctive flora grows on the cliff faces and rock overhangs associated with the heaths of the plateau edge. These rock faces receive seepage moisture, and are particularly rich in epacrids such as *Epacris reclinata, Dracophyllum secundatum* and *Sprengelia monticola* and the fern, *Gleichenia rupestris.* The endangered species *Microstrobos fitzgeraldii* is a notable inhabitant of rock faces within the spray zone of waterfalls (Smith 1981).

Map unit 21c occurs on Shoalhaven Group sandstones on Ti Willa Plateau and Kanangra Tops, while on exposed south-eastern parts of the Boyd Plateau it may be found on metamorphic rocks of the Devonian Lambie Group. The latter is characterized by tall, thick growth of *Eucalyptus stricta*, often forming a closed-scrub with occasional shrubs of *Banksia marginata, Acacia dorothea, Isopogon anemonifolius* and *Allocasuarina nana* below. By contrast, *E. stricta* is absent from much of Kanangra Tops where thickets of *Allocasuarina nana* and

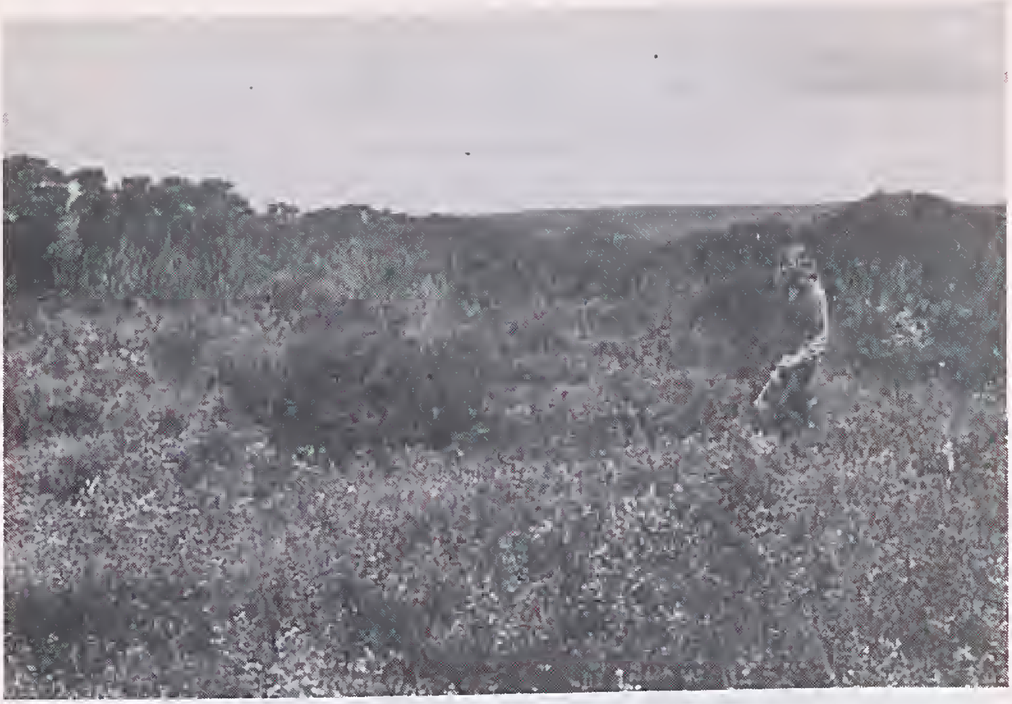

Figure 7. 'Montane Heath' on Mt Thurat (map unit 21c) showing *Banksia marginata, Epacris microphylla* (flowering) and *Dillwynia phylicoides*, with clumps of *Eucalyptus stricta* in the background.

bare rock platforms alternate with *Baeckea brevifolia* on shallow humic soils in poorly-drained depressions. Several species noted on Kanangra Tops, including *Prostanthera saxicola* var. *montana* and *Leptospermum* sp. nov. 'Y' were not found on the heaths of the Blue Mountains Plateau to the east. However, these western heaths generally show lower species richness than those of the Blue Mountains.

Map unit 21d 'Pagoda Rock Complex'.

Open-heath: *Allocasuarina nana–Leptospermum arachnoides–Lepidosperma viscidum.*

Open-scrub: *Eucalyptus* sp. nov. 'MOKII'.

Woodland: *E. sieberi–E. piperita.*

This mosaic of vegetation types is found in the Wollangambe Wilderness amongst the 'beehive' or 'pagoda' formations of the Narrabeen Group sandstones (Benson 1984). On the exposed, rocky outcrops is an open-heath of *Allocasuarina nana, Leptospermum arachnoides, Platysace lanceolata* and *Banksia ericifolia*, sometimes interspersed with clumps of the mallee, *Eucalyptus* sp. nov. 'MOKII', though generally resembling map unit 21c. In more sheltered situations there is woodland, similar to map unit 9i, with *E. piperita* ssp. *piperita, E. sieberi, E. oblonga* and *E. sclerophylla*. Common understorey species include *Daviesia latifolia, Dillwynia retorta, Acacia terminalis, A. dorothea, Boronia microphylla, Hakea dactyloides* and *Allocasuarina distyla*.

Map unit 21f 'Lower Blue Mountains Heath'.

Open-heath: *Eucalyptus stricta–Allocasuarina nana–Leptospermum attenuatum–Phyllota phylicoides–Eriostemon hispidulus.*

Open-heath: *Epacris reclinata–Dracophyllum secundatum–Gleichenia rupestris.*

This heath community occurs below 850–900 m elevation on Kings Tableland, Sublime Point, Linden Ridge and in the Mt Hay area. The most conspicuous species include many of the 'ubiquitous' heath species common in Community 21c. However, a number of small shrubs including *Epacris rigida, Hemigenia purpurea, Daviesia corymbosa, Phyllota phylicoides, Pultenaea elliptica, Darwinia fascicularis* ssp. *oligantha*, and the sedge, *Lepidosperma neesii* may be regarded as typical low elevation constituents.

Cliff faces and rock overhangs support a similar flora to that described for map unit 21c.

Map unit 26a 'Blue Mountains Sedge Swamps'.

Closed-sedgeland: *Gymnoschoenus sphaerocephalus–Lepidosperma limicola–Xyris ustulata–Baeckea linifolia.*

In contrast to the shrub swamps of the Upper Mountains (map unit 20a), swamps in the headwater valleys of the sandstone plateau below 1000 m elevation, are dominated by sedges. These swamps occupy steep-sided basins, up to 35 ha in area. The upper boundary is often a clearly defined rim coinciding with the outcropping of a claystone stratum. This acts as an aquiclude (Holland 1974) and directs water to the surface at the rim to form a swamp below (Figure 8).

Swamps on steep valley sides (often known as hanging swamps) are intermittently waterlogged and have shallow, sandy soils with a moderate organic content. They have open-heath vegetation with shrubs of *Hakea teretifolia, Leptospermum squarrosum, Epacris obtusifolia, E. microphylla, Sprengelia incarnata, Hibbertia cistiflora, Dampiera stricta* and *Pultenaea incurvata*, and sedges such as *Ptilanthelium deustum, Leptocarpus tenax, Empodisma minus* and *Lepyrodia scariosa*. In contrast, valley bottoms support closed-sedgeland on finer grained, deeper, highly organic sediments that are frequently waterlogged and permanently wet. There are fewer species here than on the more freely-draining slopes, characteristically *Gymnoschoenus sphaerocephalus, Lepidosperma limicola, Empodisma minus* and *Xyris ustulata* with occasional shrubs of *Baeckea linifolia, Leptospermum lanigerum, Acacia ptychoclada* and *Pultenaea divaricata.*

In some cases there is a distinct wet heath/woodland (map unit 9i) vegetation boundary but in others, there is a broader transition zone from wet heath to dry heath (map unit 21f).

Map unit 26b 'Boyd Plateau Bogs'.

Closed-sedgeland: *Carex appressa–C. gaudichaudiana–Juncus holoschoenus–Baeckea utilis.*

Closed-heath: *Leptospermum myrtifolium–L. obovatum–L. lanigerum.*

Swamps in headwater valleys on the Boyd Plateau are entirely different to those on the Blue Mountains sandstone plateau (map unit 26a). They occur at higher altitudes (ca. 1200 m), consist of soils derived from granite parent material, probably with a higher nutrient status, and occupy relatively shallow valleys compared to the hanging swamps in the Blue Mountains.

Vegetation patterning within the Boyd swamps appears to relate primarily to waterlogging regimes, but has probably also been affected by fire and grazing. The most widespread vegetation type is a closed-sedgeland of *Carex appressa, C. gaudichaudiana, Juncus holoschoenus* ssp. *fockei, Restio australis, Agrostis hiemalis* and *Deyeuxia gunniana* with other herbs including *Patersonia fragilis, Asperula gunnii* and *Geranium neglectum* and emergent shrubs of *Epacris paludosa, Hakea microcarpa* and *Baeckea utilis*. Thickets of *Leptospermum myrtifolium, L. lanigerum, L. obovatum* and *Callistemon sieberi* may occur

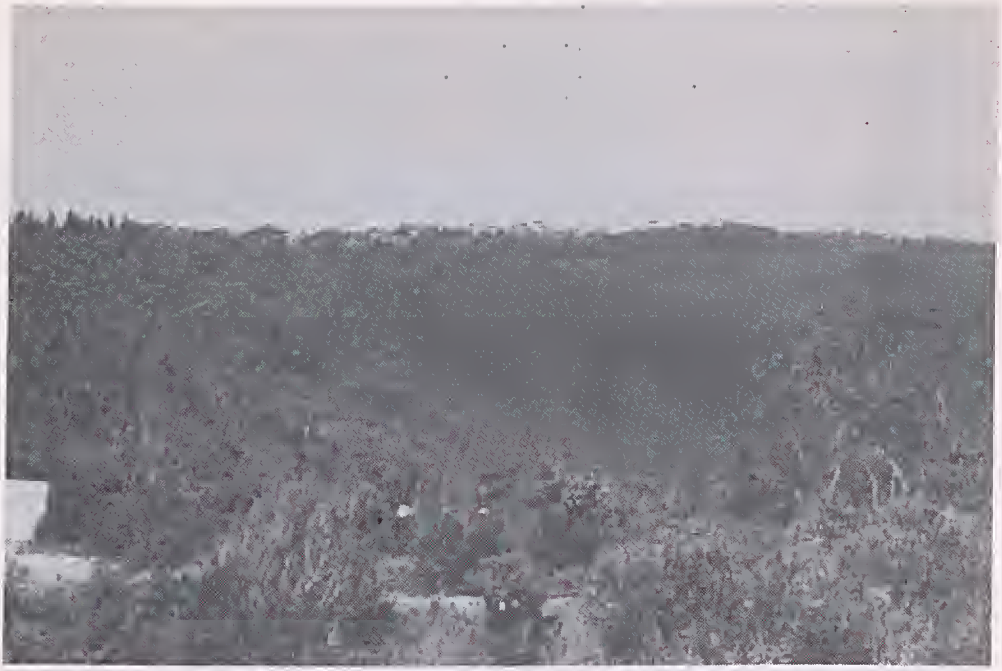

Figure 8. Kings Tableland, a plateau of Narrabeen Sandstone, showing *Eucalyptus sieberi* woodland (map unit 9i) on upper slopes grading into 'Montane Heath' (map unit 21c) in right background. The 'Sedge Swamp' (map unit 26a) has a clearly defined boundary with the woodland above, related to the outcropping Wentworth Falls Claystone.

sporadically, while more open areas with *Amphipogon strictus, Empodisma minus, Lepidosperma filiforme, Wahlenbergia ceracea* and *Helichrysum bracteatum* can often be seen around the margins.

The presence of species such as *Celmisia* sp. aff. *longifolia, Wahlenbergia ceracea* and *Sphagnum* sp. indicates that the Boyd swamps share floristic affinities with the alpine and subalpine bogs of the Southern Tablelands.

Discussion

Vegetation patterns

The patterns of vegetation in the area covered by the Katoomba map sheet relate to soils, physiography and elevation, and in particular to geology. Cross-section diagrams on the map sheet depict the relationships between vegetation and geology. Many plant communities are found only on particular soil types and are directly related to their parent geology. For example, communities in map units 6d and 9x are restricted to river alluvium, those in 6e and 6g relate to diatremes and basalt flows respectively, while map unit 9a is found only on ridges capped by Wianamatta Shale, and units 26a and 26b are restricted to waterlogged soils derived from sandstone and granite respectively. Carne (1908) aptly remarked,

> 'The influence of geological conditions on botany is so pronounced and distinctive in insular areas on the sandstone plateau as to arrest the attention even of those unfamiliar with the cause . . . '

On the western part of the map area, however, the major map units (9n, 10r, 10s and 10l) occur on two or more different geological substrates. This may be due to the derivation of a similar range of soil types from the different rocks or the overriding effect of the cold climate restricting the number of species able to grow in this area.

Physiography influences the degree of exposure, soil formation and the availability of water at a particular site. Extreme examples are heath communities (map units 21c and 21f) found on exposed ridge crests, and rainforests (8c and 8d) which are found in moist, well sheltered gullies and slopes. Floristic differences between subunits 10ag and 10ar relate specifically to their different physiographic environments as they occur on the same parent material in similar climatic conditions.

There is a significant variation in rainfall, minimum temperatures and the occurrence of frosts and snow over the altitudinal range in the area covered by the Katoomba sheet. Groups of communities on similar soils, geology and physiography may form altitudinal series. For example, 10a–9i–10r on sandstone plateaux, 6h–9j on Permian escarpments, 10q–9m–10h on undulating Shoalhaven Group sediments, 21f–21c on exposed sandstone ridges and 26a–20a in sandstone headwater valleys. The Blue Mountains area offers excellent opportunities for research on the relationships between species distributions and altitudinal gradients.

Conservation

Large areas of natural vegetation on the Katoomba map sheet have been dedicated as reserves for nature conservation. Some 140 000 ha are included within Blue Mountains and Kanangra-Boyd National Parks (Figure 9). Smaller reserves include the Forestry Commission's proposed Forest Preserve at Beefsteak Creek near Black Range and several important Council Reserves in the Blue Mountains, including Waterfall Reserve at Mt Wilson and Coachwood Glen at Blackheath. Regrettably some of these reserves cannot always guarantee the long term protection and management of the biological resources they contain. In particular, Council Reserves and Forest Preserves may be subject to changes in zoning and local management priorities. Plant communities can only be regarded as adequately conserved if representative samples of their geographic and ecological ranges are included within Nature Reserves, National Parks or Flora Reserves, as these are protected by State legislation.

Plant communities in the Katoomba region are not evenly represented within the reserve system (Table 3). In fact five map units (9i, 10ag, 10ar, 10p and 10q) account for most of the area covered by the two National Parks. Ten of the 32 Katoomba map units are not represented in reserves at all. They are 6d, 9a, 9j, 9x, 10h, 10m, 10o, 10t, 17a and 20b. A further six (6c, 8c, 8d, 10r, 20a, 21d) are represented by only small examples in reserves.

A number of the larger poorly conserved map units persist as remnants in the Coxs River valley. 'Yellow Box Woodland' (map unit 10o) has been extensively cleared for agriculture around Hartley. Part of the largest remnant in the Little River area is the subject of the National Parks Association's proposed Little/Coxs River Addition to Kanangra-Boyd National Park (Byrne 1987). This is the only opportunity to conserve a sample of 'Yellow Box Woodland' in the Katoomba area. The 'Tablelands Grassy Woodland Complex' (map unit 10h) has also been largely cleared though small areas persist around Hartley Vale. Larger unprotected remnants are found to the north around Ben Bullen, Cullen Bullen and west of Lidsdale. 'Coxs River Swamps' (map unit 20b) have a naturally restricted distribution. Unprotected examples are found near Nellies Glen, at Kerosene

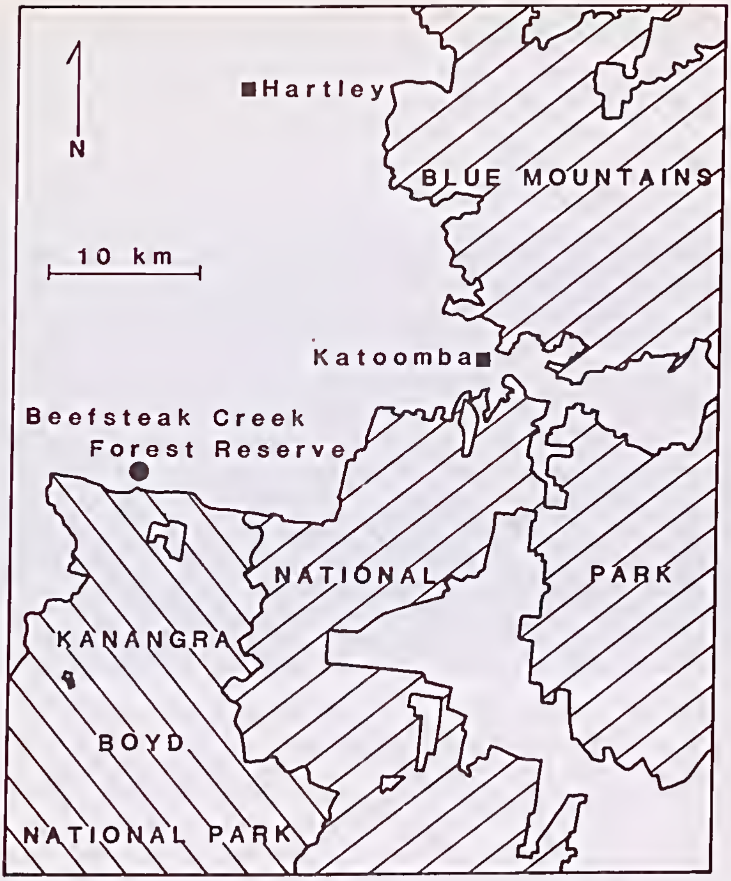

Figure 9. Location of conservation reserves in the area covered by the Katoomba map sheet.

Creek, and to the east of Cullen Bullen, further north (Benson 1984). These swamps are affected by grazing to varying degrees. 'River Oak Forest' (map unit 9x), although remnants are usually weed-infested, has survived in many places along the banks of Coxs River in the predominantly agricultural Megalong Valley. Smaller, unmapped stands occur downstream in the Blue Mountains National Park, while larger areas are found further south along the Wollondilly River.

Map unit 10m, although unprotected, has remained relatively undisturbed because of its rough terrain and unsuitability for agriculture. The National Parks Association of New South Wales has a Nature Reserve proposal for an area west of Lithgow. If this proceeds this vegetation will be adequately conserved. Large unprotected areas of map unit 9j remain on the escarpment slopes between Mount Victoria and Lithgow. These have been selectively logged in places, but remain relatively undisturbed due to their rough terrain. Numerous gullies supporting this vegetation are found in the south-west of Wollemi National Park.

Most of the other poorly-conserved map units have naturally restricted distributions. Map units 6d and 10t have very restricted distributions and occur only on private property in the Kedumba and Coxs River valleys respectively. 'Shale Cap Forest' (map unit 9a) is also restricted to small areas on private property and has been largely cleared for agriculture. A small stand of somewhat similar vegetation is conserved in Wollemi National Park at Culoul Range (Benson 1980).

Table 3: Major conservation reserves in the area covered by the Katoomba 1:100 000 vegetation map sheet.

Reserve	Administered by	Approximate area (ha)	Map units included
Blue Mountains National Park	NP&WS	100 000	6c*, 6g, 6h, 8c*, 8d*, 9i, 9m, 10ag, 10ar, 10p, 10q, 20a*, 21c, 21d*, 21f, 26a
Kanangra-Boyd National Park	NP&WS	40 000	9n, 101, 10p, 10r*, 10s, 10u, 17a, 21c, 26b
Beefsteak Creek Forest Preserve (Proposed)	FC	200	9n, 10s

Map units not represented: 6d, 9a, 9j, 9x, 10h, 10m, 10o, 10t, 17a, 20b
* represented by small examples only
NP&WS = National Parks and Wildlife Service
FC = Forestry Commission of New South Wales

Other areas of this community have been almost completely cleared from the ridges around Springwood. 'Montane Rainforest' (map units 8c) and 'Moist Basalt Cap Rainforest' (map unit 6g) also have restricted distributions. Small areas are represented in Blue Mountains and Wollemi National Parks, though much of the remainder occurs in Council Reserves at Mount Wilson and Coachwood Glen (Pulpit Hill Creek, Blackheath). Similarly, small areas of map unit 10r are represented in Kanangra-Boyd National Park while a number of other remnants are found further north in forestry and agricultural areas at Black Range, Gibraltar Rocks, Table Mountain, Mount Arthur, Cheetham and Old Bowenfels.

Small 'Newnes Plateau Shrub Swamps' (map unit 20a) occur in Blue Mountains National Park near Bell, though much larger examples of these interesting swamps remain unprotected on the Newnes Plateau to the north (Benson 1984). Other restricted types include 'Black Range Scrub' (map unit 17a), found only in Jenolan State Forest; 'Glen Forest' (6c), represented by very small stands in Blue Mountains National Park; and 'Kowmung Dry Rainforest' (8d), restricted to Kanangra-Boyd National Park.

Plant communities on the Triassic sandstone plateau are generally well conserved. However, the area between Wentworth Falls and the Kedumba Valley gate on Kings Tableland warrants special consideration. The heath in this area (part of map unit 21f) represents an important part of the overall altitudinal sequence in Blue Mountains heath communities. At an elevation of 830–880 m it represents an intermediate position where a number of high and low altitude heath species co-exist. Nineteen rare or significant species (Table 4) are also found in this area.

Sixty-five significant species are listed for the Katoomba map sheet area (Table 4), 41 of which are also listed by Leigh, Briggs & Hartley (1981). These species are either rare, threatened or of botanical significance in terms of geographic distribution. The list contains species of varying rarity and conservation status: *Olearia oliganthema* has not been collected since 1866 and is presumed to be extinct (Leigh, Briggs & Boden 1984); *Microstrobos fitzgeraldii* is vulnerable and threatened (Smith 1981); *Melaleuca armillaris*, although common in coastal situations is restricted on the tablelands; while *Hibbertia saligna* appears to be adequately conserved with numerous populations in the Blue Mountains

National Park. There are a high number of locally restricted species for the map area, and particularly along the escarpment from Kings Tableland, through Wentworth Falls, Leura and Katoomba to Narrowneck Peninsula. Workers involved in the preparation of environmental impact statements, plans of management, conservation studies etc., should be aware of the significance of these species if present in their study area.

The number of significant plant communities and species found in the area covered by the Katoomba map sheet is high when compared with other parts of the Sydney region (lists for Gosford–Lake Macquarie, St Albans, Wallerawang, Sydney and Penrith map sheets are held at the Royal Botanic Gardens, Sydney). Twenty of the 65 significant species listed in Table 4 are endemic to the greater Blue Mountains region. Bearing in mind the strong altitudinal trends in the vegetation, the restricted distributions of many species may be related to climatic fluctuations in the past. Many species now restricted to higher elevations may have been more widespread in cooler times, particularly those which are represented by disjunct populations.

Management issues

Despite the large area set aside to protect the natural environment, the concentration of suburban development along the major linear ridge systems followed by the Great Western Highway and Bells Line of Road will have a long-term impact on a proportionally greater area. The main effects on vegetation, apart from the obvious direct impact of future clearing, will be through increasing effluent runoff from adjacent built-up areas (Bliss, Riley & Adamson 1983). This contains silt and nutrients which promote the invasion of exotic weed species, such as *Lonicera japonica* and *Ligustrum* species, into previously undisturbed bush. The heads of many creeks and gullies around Katoomba and Wentworth Falls already have a high component of exotic species. This is a serious and increasing problem that needs further documentation and treatment.

The other main effects of adjacent development are from changes in the bushfire regime, which may be either reduced or increased depending on the site. Either way the vegetation may be changed, and it is only with continuing research into the response of native plant communities and individual species to fire, that predictions and successful management of these impacts can be accomplished.

Acknowledgements

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Table 4: Species of particular conservation significance within the Katoomba 1:100 000 map sheet area.

Species listed here are either rare or threatened (Leigh, Briggs & Hartley, 1981), or of botanical significance in terms of geographic distribution. Localities refer to Katoomba map sheet occurrences. Nth. = northern, Sth. = southern, codings (2X, 2V, 2VC, 3V, 2RC, 3RC, 2K) are from Leigh, *et al.* (1981).

Species (family)	Habitat/Locality	Significance
FERNS		
ASPIDIACEAE		
Lastreopsis hispida	Rainforest, Mt Wilson	Local disjunct population
BLECHNACEAE		
Blechnum gregsonii	Lawson, Mt Wilson, Wentworth Falls	2V
HYMENOPHYLLACEAE		
Hymenophyllum pumilum	Rainforest, Mt Tomah	3RC, very rare
Sphaerocionium lyallii	Rainforest, Wentworth Falls	3RC
GYMNOSPERMS		
PODOCARPACEAE		
Microstrobos fitzgeraldii	Within spray of waterfalls, Wentworth Falls to Katoomba	2V, highly restricted local endemic
DICOTYLEDONS		
APIACEAE		
Xanthosia dissecta	Swamps, Wentworth Falls	Local disjunct population
ASTERACEAE		
Celmisia sp. nov. aff. *longifolia*	Wentworth Falls, Blackheath	Local disjunct population
Olearia oliganthema	Blue Mountains	2X, local endemic
Olearia quercifolia	Swamps, Wentworth Falls to Clarence	2RC, local endemic
CAMPANULACEAE		
Wahlenbergia ceracea	Swamps, Boyd Plateau	Local disjunct population
CUNONIACEAE		
Acrophyllum australe (Calycomis australis)	Woodford–Linden	3V, local endemic
DILLENIACEAE		
Hibbertia saligna	Mt Wilson, Mt Tomah, Wentworth Falls, Springwood	2RC
EPACRIDACEAE		
Epacris apiculata	Rock ledges, Wentworth Falls	3RC
Epacris hamiltonii	Only known from Blackheath	3RC, highly restricted local endemic
Epacris muelleri	Damp rocks, Blackheath Mt Wilson	3RC
Leucopogon sp. aff. *appressus*	Rocky outcrops, Bedford Ridge	Local form
Lissanthe sapida	Blue Mountains	2RC
Rupicola sprengelioides	Blue Mountains	3RC
Sprengelia monticola	Wet rock ledges, upper Blue Mountains	3RC
EUPHORBIACEAE		
Beyeria lasiocarpa	Jenolan River gorge	Local disjunct population
Pseudanthus divaricatissimus	Heath, Narrow Neck & Kings Tableland	3RC

Species (family)	Habitat/Locality	Significance
FABACEAE		
Acacia asparagoides	Glen Davis–Lawson	Local endemic
Acacia baueri ssp. *aspera*	Kings Tableland, Wentworth Falls	Local disjunct population, also near Wilton
Acacia bynoeana	Hazelbrook–Bell	3V
Acacia clunies-rossii	Coxs, Kowmung Rivers, Yerranderie	2V
Acacia hamiltoniana	Bell to Mt Wilson	Uncommon
Acacia ptychoclada	Swamps & creek banks, Woodford to Mt Victoria	Local endemic
Mirbelia baueri	Kings Tableland	Local disjunct population Nth. limit
Pultenaea echinula	Kings Tableland, Mt Victoria, Cyrils Rocks	Local endemic
Pultenaea glabra	Wentworth Falls–Katoomba	3V
Pultenaea incurvata	Wentworth Falls–Clarence	2RC, local endemic
GERANIACEAE		
Geranium graniticola	Kanangra to Oberon	3RC
GOODENIACEAE		
Goodenia rostrivalvis	Lawson to Leura	2RC
Scaevola hookeri	Blackheath	Local population
LORANTHACEAE		
Atkinsonia ligustrina	Linden, Bedford Ck, Mt Wilson, Bilpin	2K
MYRTACEAE		
Darwinia fascicularis ssp. *oligantha*	Mt Banks–Wentworth Falls	Local endemic
Eucalyptus baeuerlenii	Terraces of south-facing cliffines, Wentworth Falls	3RC, local disjunct population Nth. limit
Eucalyptus benthamii	Alluvium, Kedumba Valley	3RC, local endemic
Eucalyptus burgessiana	Ridges, Linden, Mt Tomah	2VC, local endemic
Eucalyptus gregsoniana	Blackheath–Clarence, Budawangs	3V, local disjunct population
Eucalyptus ligustrina	Kings Tableland	Local disjunct population
Eucalyptus macarthurii	Boyd Crossing	3V, local disjunct population, Nth. limit
Eucalyptus moorei	Narrow Neck, Bell	Local disjunct population
Eucalyptus pulverulenta	Mt Blaxland, Lowther Ck.	3V, local disjunct population Nth. limit
Eucalyptus rupicola	Cliff edges, Wentworth Falls–Katoomba	2RC
Kunzea sp. nov.	Amongst rocks, Mt Cookem	Local endemic
Leptospermum sp. nov. 'L'	Heath, woodland, Hassans Walls	2R, local endemic
Leptospermum sp. nov. 'R'	Cliffs, Kings Tableland–Glen Davis	Local population
Leptospermum sp. nov. 'Y'	Mallee heath, Kanangra	Local endemic
Melaleuca armillaris	Jenolan River gorge	Local disjunct population
Melaleuca squamea	Wentworth Falls, Blackheath	Uncommon
PROTEACEAE		
Grevillea obtusifolia	Kedumba Valley, Kiaramba Ridge	3V, local endemic, Rylstone-Kedumba
Grevillea rosmarinifolia	Coxs River, Glenroy Crossing	Type form, now presumed extinct

Species (family)	Habitat/Locality	Significance
Hakea constablei	Kings Tableland, Mt Wilson–Mt Banks	3V, local endemic
Isopogon fletcheri	Found only at Govetts Leap, Blackheath	2VC, highly restricted, local endemic
Persoonia acerosa	Valley Heights–Clarence	Local endemic
RUTACEAE		
Boronia deanei	Swamps, Boyd Plateau	2VC, local pop., also near Newnes & Nerriga
Eriostemon obovalis	Blackheath–Bell	2RC
Zieria sp. nov. 'F'	Narrow Neck	2VC, local endemic
SCROPHULARIACEAE		
Parahebe sp. (Mt Colong)	Kanangra–Mt Colong, McMahons Lookout, on rocky outcrops	2RC, local endemic
MONOCOTYLEDONS		
LILIACEAE		
Allania endlicheri	Gullies on moist rocks, Mt Corricudgy–Linden	3RC
Blandfordia cunninghamii	Wentworth Falls, Mt Tomah	3RC, local population
ORCHIDACEAE		
Adenochilus nortonii	Woodford–Mt Victoria	3V
Prasophyllum ansatum	Mt Wilson–Bell	3RC
POACEAE		
Deyeuxia microseta	Forests, higher altitudes	3V
Notochloe microdon	Swamps, higher altitudes	2RC

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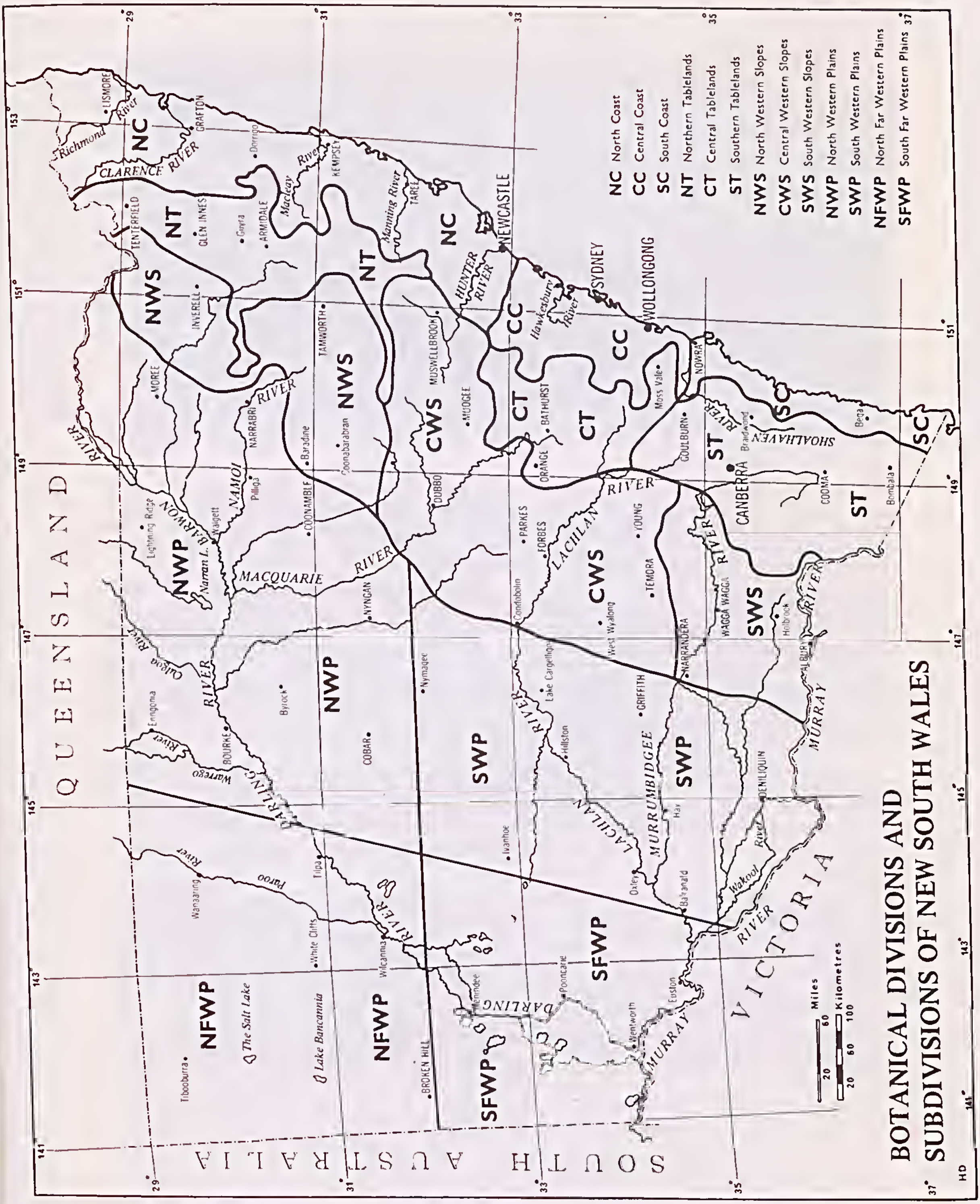

For explanation and description of the Botanical Divisions and Subdivisions of New South Wales see Anderson, R. H. (1961). Introduction. *Contr. New South Wales Natl. Herb. Fl. New South Wales* Nos 1–18, pp. 1–15.

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Manuscripts. Two copies of the manuscript, each accompanied by copies of all illustrations, should be sent to the Editor, *Cunninghamia*, National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, 2000. They should be typed double-spaced on one side only of the paper, with ample margins. Style should follow that of a recent issue. The full postal address of the author who will check the proofs and receive correspondence should be included, as well as the present address of any author if different from that where the work was carried out. All pages should be numbered consecutively. The main title should be explicit and descriptive of the content of the paper; a short running title should also be provided. It would be helpful if authors could indicate in the margin the relative importance of headings by use of ringed capital letters, e.g. (A) for main headings, (B) for secondary headings and (C) for tertiary headings, etc. Footnotes within the text should be used only when essential. They should be placed below a horizontal line at the foot of the page.

Abbreviations, units, etc. SI units (metre, kilogram, etc.) are to be used. Statistics and measurements should always be given in figures, e.g. 10 mm, except where the number begins the sentence. The *Style Manual for Authors, Editors and Printers*, 4th edn, AGPS, 1988, should be consulted for spelling, abbreviations and other conventions.

Tables. The presentation of the same data in both graphical and tabular form should be avoided. Tables must be clearly headed and, if possible, self-explanatory. They must be typed on separate sheets and should be numbered consecutively with arabic numerals. Column headings should be brief with units of measurements in parentheses. Each table must be referred to in the text and its approximate position should be indicated in the margin of the manuscript.

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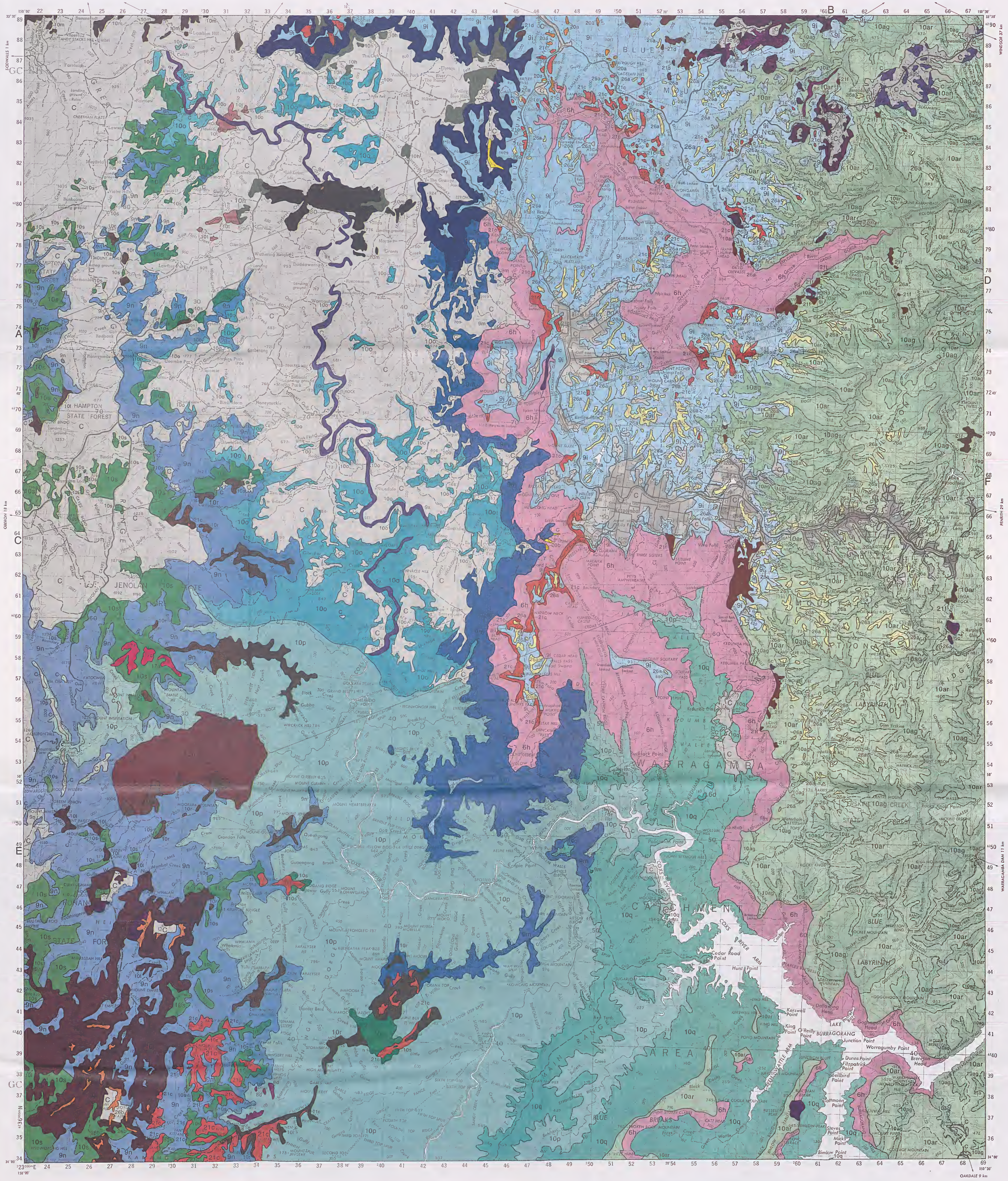


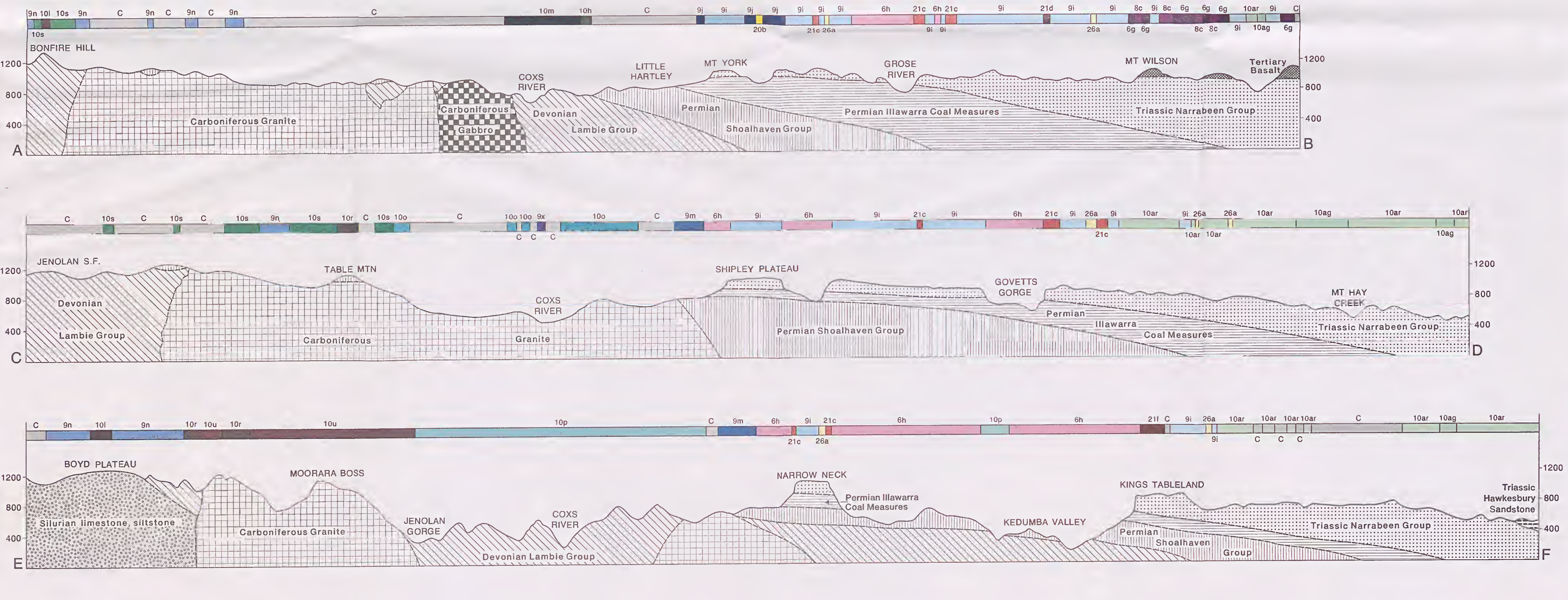
MAP UNIT DESCRIPTION

MAP UNIT	STRUCTURE	MAIN CANOPY SPECIES	GEOLOGY	ALTITUDE	HABITAT
	'Glan Forest'				
	TALL OPEN-FOREST	*Eucalyptus deanei* *Syncarpia glomulifera*	Jurassic diatremes	<650m	Amphitheatre-shaped gullies
6d	**'Camden White Gum Forast'**				
	TALL OPEN-FOREST	*Eucalyptus benthamii* *E. deanei*	Recent alluvium	<150m	Banks of Kedumba River
	'Moist Basalt Cap Forast'				
	TALL OPEN-FOREST	*Eucalyptus viminalis* *E. blaxlandii* *E. fastigata*	Basalt caps	>800m	Ridges and slopes of residual basalt
6h	**'Escarpmant Complax'**				
	TALL OPEN-FOREST	*Eucalyptus deanei* *E. cypellocarpa* *Syncarpia glomulifera*	Illawarra Coal Measures	120-850m	Escarpment slopes
	OPEN-FOREST	*Angophora costata* ssp. *costata* *Eucalyptus piperita* ssp. *piperita* *E. punctata*	Shoalhaven Group	120-850m	Undulating country below escarpment slopes
	CLOSED-FOREST	*Ceratopetalum apetalum* *Doryphora sassafras*	Illawarra Coal Measures	120-850m	Sheltered gullies on escarpment slopes
8c	**'Montane Rainforast'**				
	CLOSED-FOREST	*Ceratopetalum apetalum* *Doryphora sassafras* *Quintinia sieberi*	Illawarra Coal Measures, Tertiary basalt	600-1000m	Sheltered gullies on escarpment slopes. Also found on basalt caps
8d	**'Kowmung Dry Rainforast'**				
	CLOSED-FOREST	*Toona australis* *Ehretia acuminata* *Brachychiton populneum*	Devonian Lambie Group	300-700m	Sheltered lower slopes in deeply Kowmung area
	'Shale Cap Forest'				
	OPEN-FOREST	*Eucalyptus notabilis* *E. globoidea* *Syncarpia glomulifera*	Wianamatta Shale	<750m	Ridgetop, Berambing to Bilpin
9i	**'Blue Mountains Sandstone Plateau Forest'**				
	OPEN-FOREST	*Eucalyptus sieberi* *E. piperita* ssp. *piperita*	Narrabeen Group	800-1150m	Dissected sandstone plateaux
	'Montane Gully Forast'				
	OPEN-FOREST	*Eucalyptus fastigata* *E. cypellocarpa* *E. dalrympleana* ssp. *dalrympleana*	Narrabeen Group	850-1100m	Gorges and escarpment slopes
9m	**'Magalong Forast'**				
	OPEN-FOREST	*Angophora costata* ssp. *costata* *Eucalyptus punctata* *E. sieberi*	Shoalhaven Group	400-750m	Undulating country below escarpment slopes
9n	**'Montana Moist Forast'**				
	OPEN-FOREST	*Eucalyptus fastigata* *E. dalrympleana* ssp. *dalrympleana* *E. viminalis*	Lambie Group, Carboniferous granites	>700m	Steep slopes and moist sheltered gullies
9x	**'River Oak Forest'**				
	OPEN-FOREST	*Casuarina cunninghamiana*	Alluvium	<800m	Along major watercourses
10ag	**'Sydnay Sandstone Complex'**				
	OPEN-FOREST	*Angophora costata* ssp. *costata* *Eucalyptus piperita* ssp. *piperita* *E. agglomerata*	Narrabeen Group, Hawkesbury Sandstone	<800m	Dissected plateau, in gullies
10ar	**'Sydney Sandstone Complex'**				
	WOODLAND	*Eucalyptus gummifera* *E. sclerophylla* *E. oblonga*	Narrabeen Group, Hawkesbury Sandstone	<800m	Dissected plateau, on ridges
	'Tablalands Grassy Woodland Complax'				
	WOODLAND	*Eucalyptus dives* *E. mannifera* ssp. *mannifera* *E. eugenioides*	Shoalhaven Group	>800m	Undulating to hilly country
	WOODLAND	*E. pauciflora* ssp. *pauciflora* *E. rubida*		>800m	Valleys with frost hollows
	WOODLAND	*Eucalyptus aggregata* *E. mannifera* ssp. *mannifera* *E. stellulata*		>800m	Poorly-drained depressions
	'Snow Gum Woodland'				
	WOODLAND	*Eucalyptus pauciflora* ssp. *pauciflora* *E. dalrympleana* ssp. *dalrympleana*	Lambie Group, Carboniferous granites	>1100m	Undulating country on Great Dividing Range
	WOODLAND	*Eucalyptus pauciflora* ssp. *pauciflora* *E. rubida* *E. stellulata*		>1100m	Frost hollows
	'Mount Walker Complax'				
	WOODLAND	*Eucalyptus macrorhyncha* *E. melliodora*	Devonian Lambie Group	>600m	Rugged country around Mt Walker and south of Hartley
10o	**'Yallow Box Woodland'**				
	WOODLAND	*Eucalyptus melliodora* *E. viminalis*	Carboniferous granites	250-850m	Cox River valley

MAP UNIT DESCRIPTION

MAP UNIT	STRUCTURE	MAIN CANOPY SPECIES	GEOLOGY	ALTITUDE	HABITAT
10p	**'Kowmung Wildarness Complax'**				
	WOODLAND	*Eucalyptus tereticornis* *E. melliodora*	Devonian Lambie Group	<900m	Dissected country of the lower Cox and Kowmung Rivers. Gullies and moist slopes
	WOODLAND	*Eucalyptus fibrosa* ssp. *fibrosa* *E. crebra* *E. eugenioides* *E. punctata*	Devonian Lambie Group	<900m	Dissected country of the lowar Cox and Kowmung Rivers. Ridges and drier aspects
10q	**'Burragorang Ironbark Woodland'**				
	WOODLAND	*Eucalyptus crebra* *E. eugenioides* *E. punctata* *E. fibrosa* ssp. *fibrosa*	Shoalhaven Group	<500m	Undulating country
	WOODLAND	*Eucalyptus sclerophylla* *Angophora bakeri* ssp. *bakeri*	Shoalhaven Group	<450m	Wastern aspect of ridges in Kedumba Valley
10r	**'Rasidual Sandstona Woodland'**				
	WOODLAND	*Eucalyptus sieberi* *E. blaxlandii*	Shoalhaven Group	>900m	Rocky, high altitude ridges
10s	**'Montana Woodland'**				
	WOODLAND	*Eucalyptus radiata* ssp. *radiata* *E. dalrympleana* ssp. *dalrympleana*	Lambie Group, Carboniferous granites, Shoalhaven Group	>900m	Gentle slopes, ridges and undulating country
	WOODLAND	*E. ovata* *E. stellulata*			Poorly-drained depressions
10t	**'Mount Blaxland Complex'**				
	WOODLAND	*Eucalyptus sieberi* *E. pulverulenta*	Devonian metamorphic & igneous rocks	700-1000m	Mt. Blaxland, Wentworth's Sugarloaf
10u	**'Jenolan Granite Woodland'**				
	WOODLAND	*Eucalyptus punctata* *E.* sp. nov. "MAHEK" *E. sieberi*	Carboniferous granites	300-1100m	Steep north-facing slopes
17a	**'Black Range Scrub'**				
	OPEN-SCRUB	*Eucalyptus mannifera* ssp. *mannifera* *Leptospermum* sp. nov. "A" *L. myrtifolium* *Patersonia fragilis*	Devonian Lambie Group	1050-1150m	Soaks on southerly aspects of Black Range
20a	**'Nawnes Plataau Shrub Swamps'**				
	CLOSED-HEATH	*Leptospermum lanigerum* *Baeckea linifolia* *Grevillea acanthifolia* *Xyris ustulata*	Narrabeen Group	>1000m	Shrub-swamps in narrow headwater valleys
20b	**'Coxs River Swamps'**				
	CLOSED-HEATH	*Leptospermum obovatum* *L. flavescens* *Grevillea acanthifolia*	Illawarra Coal Measures	>600m	Valleys and headwaters of creeks
21c	**'Montana Haath'**				
	OPEN-HEATH	*Eucalyptus stricta* *Allocasuarina nana* *Leptospermum attenuatum* *Phyllota squarrosa* *Eriostemon obovalis*	Narrabeen Group	>850m	Exposed rock ridges on shallow sandy soils, often western aspects
	OPEN-HEATH	*Epacris reclinata* *Dracophyllum secundum* *Gleichenia rupestris*		>850m	Moist rock faces
	'Pagoda Rock Complex'				
	OPEN-HEATH	*Allocasuarina nana* *Leptospermum arachnoides* *Lepidosperma viscidum*	Narrabeen Group	>750m	Exposed sites on rock outcrops with shallow soils. Associated with extensive rocky platforms and "pagoda" rock formations
	OPEN-SCRUB	*Eucalyptus* sp. nov. "MOKII"		>750m	
	WOODLAND	*Eucalypyus sieberi* *E. piperita* ssp. *piperita*		>750m	Small sheltered gullies between rocky knolls
	'Lowar Blue Mountains Haath'				
	OPEN-HEATH	*Eucalyptus stricta* *Allocasuarina nana* *Leptospermum attenuatum* *Phyllota phylicoides* *Eriostemon hispidulus*	Narrabeen Sandstone	<850m	Exposed rocky ridges, often on western aspects of escarpment tops
	OPEN-HEATH	*Epacris reclinata* *Dracophyllum secundum* *Gleichenia rupestris*		<850m	Moist rock
26a	**'Blue Mountains Sedge Swamps'**				
	CLOSED-SEDGELAND	*Gymnoschoenus sphaerocephalus* *Lapidosperma limicola* *Xyris ustulata* *Baeckea linifolia*	Narrabeen Sandstone with peaty sand	<1000m	Headwater gullies or on hillsides
26b	**'Boyd Plataau Bogs'**				
	CLOSED-SEDGELAND	*Carex appressa* *C. gaudichaudiana* *Juncus holoschoenus* ssp. *fockei* *Baeckea utilis*	Carboniferous granite with acid peats.	>1200m	Headwater gullies
	CLOSED-HEATH	*Leptospermum myrtifolium* *L. obovatum* *L. lanigerum*		>1200m	Headwater gullies
C	CLEARED:	Native vegetation has been largely removed for agricultural, industrial or urban development but remnant vegetation of varying sizes and condition may remain.			

Schematic profiles showing relationships between map units, geology and topography.



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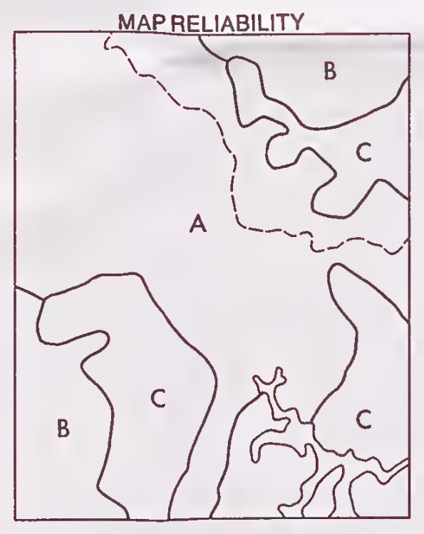
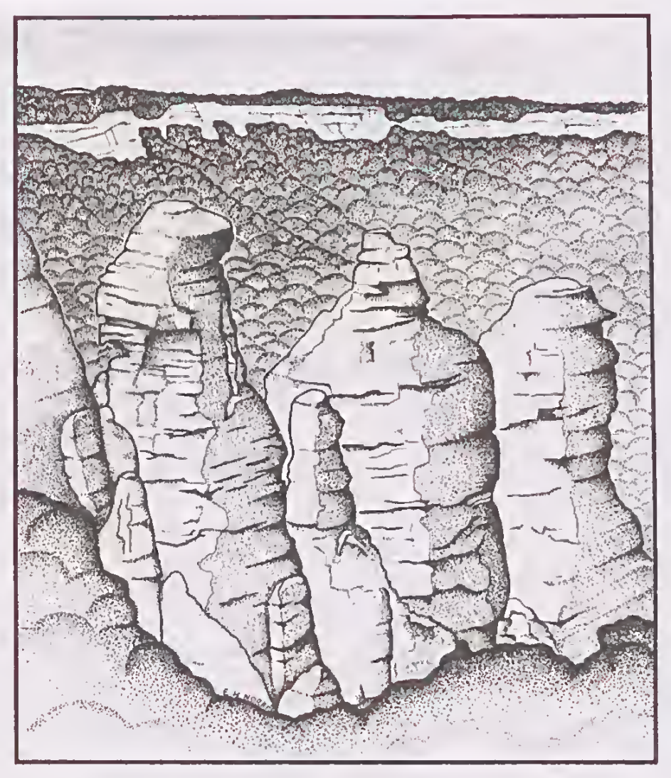


A Aerial photograph interpretation with extensive field reconnaissance.

B Aerial photograph interpretation with limited field reconnaissance.

C Aerial photograph interpretation only.



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OBERON 8830	KATOOMBA 8930	PENRITH 9030
TARALGA 8829	BURRAGORANG 8929	WOLLONGONG 9029

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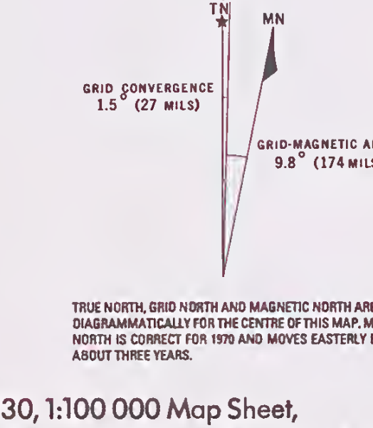
IN THE 1:250 000 SCALE SERIES


GN
TN
MN
GRID CONVERGENCE 1.5° (27 MILS)
GRID-MAGNETIC ANGLE 9.8° (174 MILS)

TRUE NORTH, GRID NORTH AND MAGNETIC NORTH ARE SHOWN DIAGRAMMATICALLY FOR THE CENTRE OF THIS MAP. MAGNETIC NORTH IS CORRECT FOR 1970 AND MOVES EASTERLY BY 0·1° IN ABOUT THREE YEARS.

Topographic base from Katoomba 8930, 1:100 000 Map Sheet,
Australian Surveying and Land Information Group, Department of Administrative Services.

ELEVATIONS IN METRES. CONTOUR INTERVAL 20 METRES

SCALE 1:100 000

NATURAL VEGETATION
# of the
KATOOMBA
area

D.A. Keith
and
D.H. Benson

Compiled and prepared at the
NATIONAL HERBARIUM OF NEW SOUTH WALES,
ROYAL BOTANIC GARDENS, SYDNEY.
To accompany CUNNINGHAMIA VOLUME 2, NUMBER 1, 1988.

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NATURAL VEGETATION
# of the
KATOOMBA

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